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Innovating in the fourth industrial revolution: disentangling trends and trajectories

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Abstract

Objectives of the paper: *This study aims to analyze the existing literature on Industry 4.0 in business and management, with a focus on innovation context. It identifies gaps in the current research knowledge and offers trends and trajectories for further research on the topic.*

Methodology: *A systematic literature review has been conducted on Industry 4.0 and innovation. We identified four themes that epitomize the current development of the literature on the topic.*

Findings: *This review highlights four six main relevant topics in management literature related to the fourth industrial revolution: 1) machines and industrial internet; 2), people and data; 3) production and consumption; and 4) Employment in the digital era. Furthermore, it identifies research gaps and highlights four emerging research themes for future researchers: 1) safety; 2) digital identity, privacy and traceability; 3) a new concept of city; and 4) sustainable mobility.*

Practical implications: *Our review on the literature will help organizations to align their innovation processes to current development of the technologies that feature Industry 4.0 revolution.*

Limitations of the research: *This study has a limitation in terms of its empirical dimensions. The future studies may conduct a meta-analysis of articles on industry 4.0 in innovation space.*

Originality: *Research on industry 4.0 and innovation is still at the embryonic stage. This study is a pioneering effort to review the existing themes that epitomize research on the topic and identify research priorities for scholars and practitioners.*

Key words: *Fourth industrial revolution, Industry 4.0; Big Data; Digital transformation*.

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1. Introduction

In the last years we have witnessed a process of technological change which presents some characteristics typical of what are normally defined as periods of combinatorial innovation (Brinjolfsson and McAfee, 2014), The entrepreneur of the digital era has today at his disposal a set of standardized components (software, protocols, interfaces, languages) that can be reshuffled and assembled in infinite combinations in order to create new products, services or processes. The basic unit of the digital age is the bit, an atom of information that does not dry up and that can be easily duplicated, combined and spread all over the world at the speed of light. This is the main difference that makes this technological revolution different from the previous ones. Today it is the beginning of a new phase and the rise of a fourth industrial revolution deeply different from the previous ones.

Differently from what happened in the past, it is thanks to the intangibility of the bit that it is easier, faster and less expensive to recombine elements and to produce new solutions, thus expanding the number of potential innovators. The most different ideas can see the light in a garage or in a college residential hall (with very poor initial investments) and then they can hugely expand in a few weeks' time through communities of innovators, thanks to the pervasivity of the Broadband Internet. Going through the list of the first ten world most capitalized companies, we can see that the first three (respectively Apple Inc., Microsoft and Google) are less than 40 years old, they have built their business around the elaboration of the digital information and they have been established in a garage.

Digital technologies activate contamination and convergence dynamics in the most different fields of the "analogic" world (Negroponte, 1996). TV, radio, cinema, photography and commercials are media that saw the light in the previous industrial revolutions (thanks to the combination of mechanics and electricity) and that in a few years' time have completely turned digital and have entered with new languages the social networks, the true new media of the Internet age. The energy field is moving towards a new smart metering and smart grid conception, while new means of urban and interurban transportation based on the sharing concept are imposing themselves on the streets of the entire world (car/bike sharing, and car-pooling),

New instruments are allowing the companies of the old economy to improve their processes and to innovate their business models by acting on different levels: as a back-office improvement instrument, as a new channel to provide the market with new products and services and as technological incentive for a change in the business model itself. However, it is not always a voluntary innovation: it is often a compulsory choice, in order to avoid the disintermediation by native digital start-up competitors, in a moment in which the ability to generate and handle the information coming from the physical world is often an opportunity to obtain long-lasting value.

The purpose of this article is to develop a discussion around the main topic and emerging trends regarding technologies underlying the fourth industrial revolution. To reach this goal the authors conducted a literature review considering the impact that technologies underlying the industry 4.0 have on business and management literature. This approach allowed the authors to develop a bird's-eye view of the most relevant topics in management and of the future trends and trajectories to be addressed.

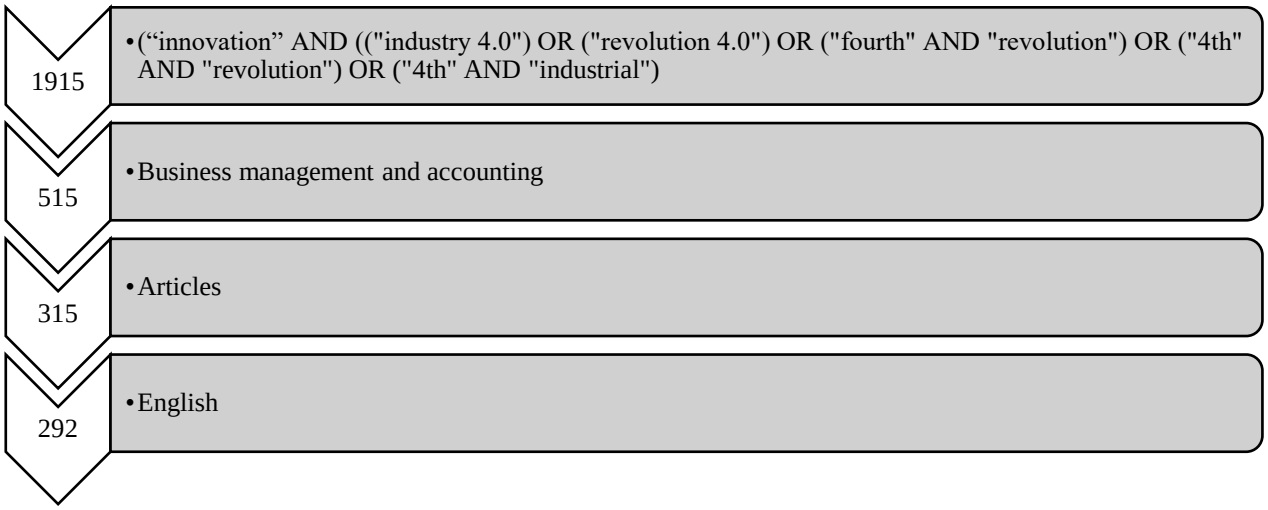
Results allowed us to identify four main relevant topics in management literature related to the fourth industrial revolution: 1) machines and industrial internet; 2) people and data; 3) production and consumption; and 4) Employment in the digital era. Moreover we identified four future trends and trajectories: 1) Safety; 2) digital identity, privacy and traceability; 3) a new concept of city; and 4) sustainable mobility.

2. Methodology

Following previous research (Dagnino *et al.*, 2021; Del Sarto *et al.*, 2018), we organised our literature review into several steps (see Figure 1). We included all papers published from 2016 to

2020 as 2016 is commonly considered as the year in which we witnessed the rise of the fourth industrial revolution. We considered the database Scopus because it is considered one of the main exhaustive academic databases. To target the fourth industrial revolution domain the following terms were considered: innovation, industry 4.0, revolution 4.0, fourth, revolution, 4th, revolution, 4th, industrial. Moreover, in order to increase the focus of results, we created the following query: TITLE-ABS-KEY (“innovation” AND (("industry 4.0") OR ("revolution 4.0") OR ("fourth" AND "revolution") OR ("4th" AND "revolution") OR ("4th" AND "industrial"))).

Fig. 1: Literature review logic flow



Source: Authors

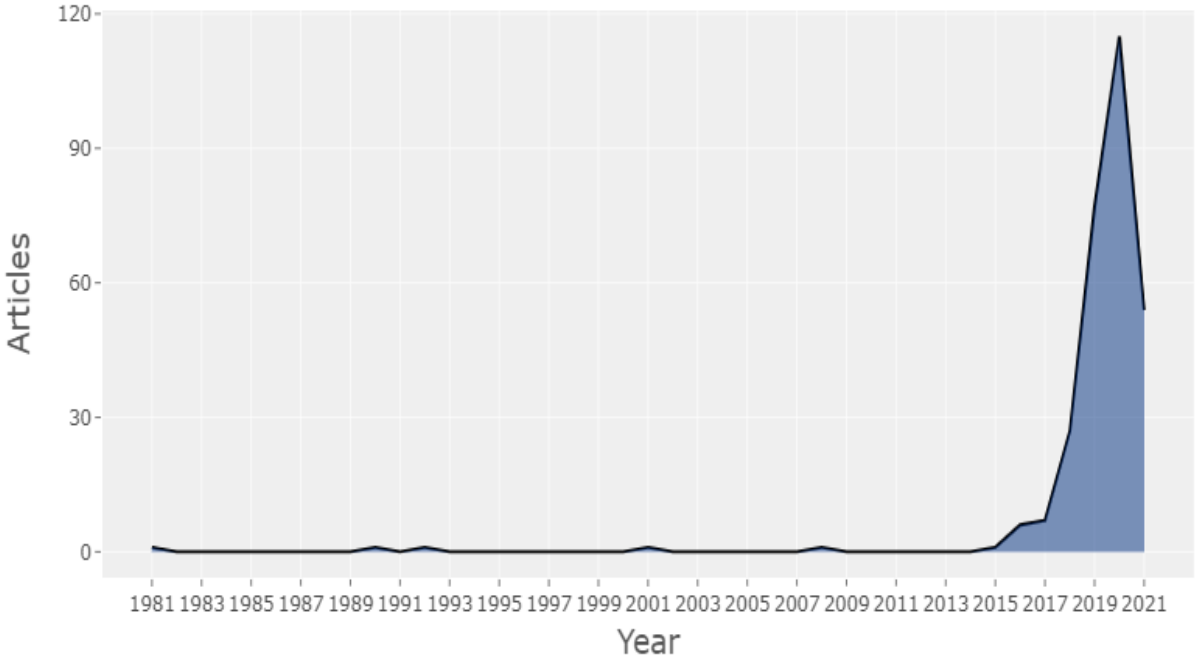
Tab. 1: Logic Flow chart used to find and select articles

Description	**Results**
Timespan	1981:2021
Sources (Journals, Books, etc)	152
Documents	292
Average years from publication	1.87
Average citations per documents	13.36
Average citations per year per doc	3.48
References	16520
DOCUMENT TYPES	
article	292
DOCUMENT CONTENTS	
Keywords Plus (ID)	920
Author's Keywords (DE)	945
AUTHORS	
Authors	820
Author Appearances	896
Authors of single-authored documents	50
Authors of multi-authored documents	770
AUTHORS COLLABORATION	
Single-authored documents	51
Documents per Author	0.356
Authors per Document	2.81
Co-Authors per Documents	3.07
Collaboration Index	3.2

Source: Authors

As reported in Table1 we included 1915 papers in the Identification step. During the Screening step we selected only paper aiming at exploring the phenomenon through a business and management perspective. This allows us to select 515 papers in the business management and accounting field. Among those documents we selected then only the articles published in academic journals, thus excluding conference papers, book chapters, books and reports. In this step we selected 315 Articles. In the last step we selected only papers in English. The end of this procedure allowed us to build a sample of 292 papers. After that, we created an Excel workbook and coded the content of each article by its author(s), journal title, subject area, investigated area, number of citations, subtopics, and methodologies (Petticrew, 2006). Two of the authors have independently read the abstracts and introduction of each article to ensure that the articles fitted the established criteria. Moreover we performed some analysis though the Bibliometrix software. In particular we show in figure 1 the annual scientific production on the topic, highlighting that since the 2015 we have seen a significant increase of published papers.

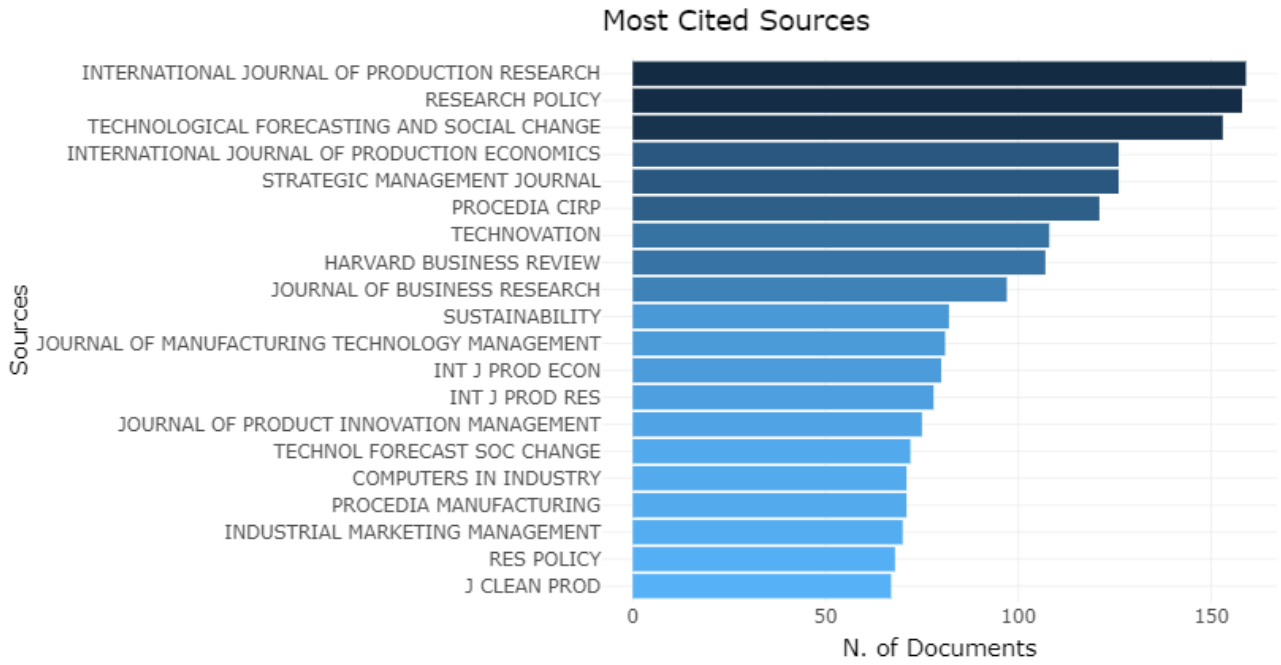
Fig. 2: Annual scientific production



Source: Authors

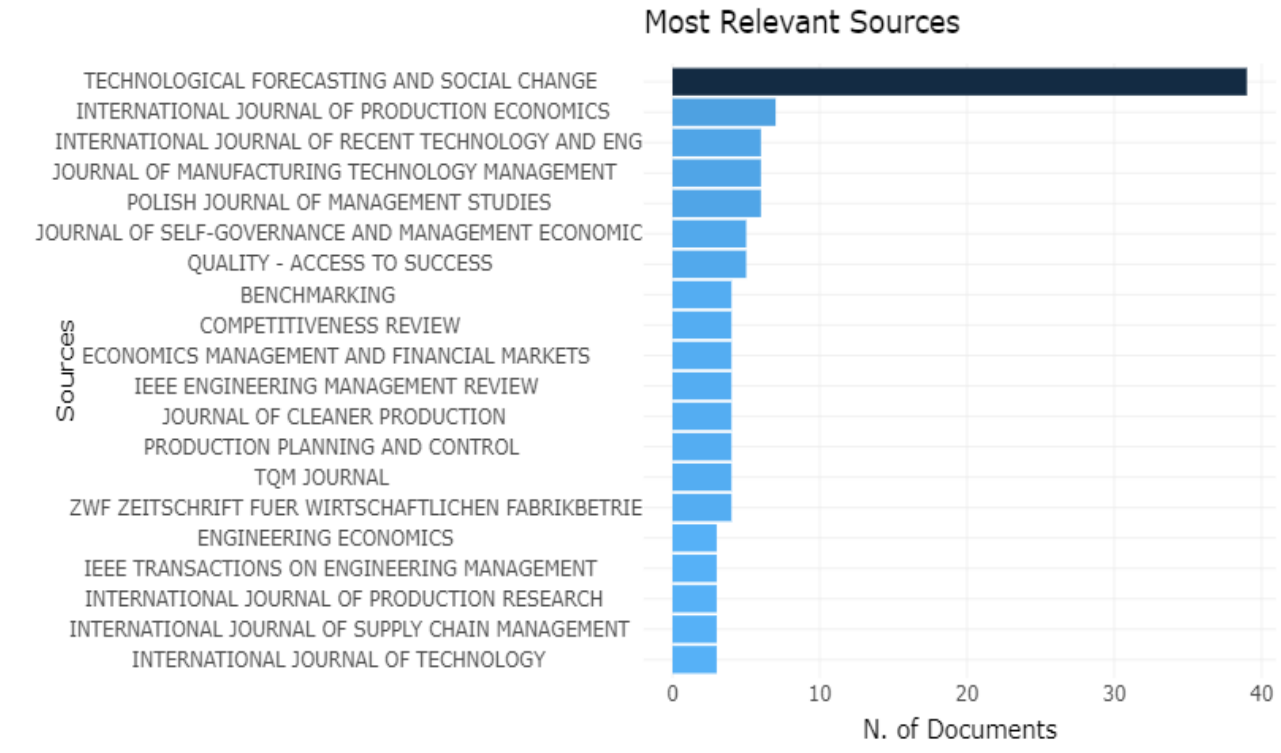
Figure 3 and Figure 4 report the most cited source and the most relevant sources respectively. The first refers to the number of citation received by the journal whereas the second refers to the number of document of each journal present in the sample. As shown by figure 3 the most cited sources are international journal of production research, research policy and technological forecasting and social change. The most relevant source is represented by technological forecasting and social change, which published a number of papers on the topic close to 40.

Fig. 3: Most cited sources



Source: Authors

Fig. 4: Most relevant sources



Source: Authors

Finally, we reported in table X the most cited documents. These papers are crucial for the identification of main topic and future trends and trajectories. Based on own reading of such documents authors have deeply understand the topic and discussed it in a plenary section together.

Tab. 2: Most cited papers

Title	Total Citations	TC per years
Rothwell, R. (1992). Successful industrial innovation: critical factors for the 1990s. R&d Management, 22(3), 221-240.	845	28.167
Li, L. (2018). China's manufacturing locus in 2025: With a comparison of "Made-in-China 2025" and "Industry 4.0". Technological Forecasting and Social Change, 135, 66-74.	237	59.25
Müller, J. M., Buliga, O., & Voigt, K. I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. Technological Forecasting and Social Change, 132, 2-17.	237	59.25
Sung, T. K. (2018). Industry 4.0: a Korea perspective. Technological forecasting and social change, 132, 40-45.	140	35
Ślusarczyk, B. (2018). Industry 4.0: Are we ready?. Polish Journal of Management Studies, 17.	121	30.25
Trantopoulos, K., von Krogh, G., Wallin, M. W., & Woerter, M. (2017). External knowledge and information technology: Implications for process innovation performance. MIS quarterly, 41(1), 287-300.	115	23
Frank, A. G., Mendes, G. H., Ayala, N. F., & Ghezzi, A. (2019). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. Technological Forecasting and Social Change, 141, 341-351.	111	37
Xu, M., David, J. M., & Kim, S. H. (2018). The fourth industrial revolution: Opportunities and challenges. International journal of financial research, 9(2), 90-95.	97	24.25
Ardito, L., Petruzzelli, A. M., Panniello, U., & Garavelli, A. C. (2019). Towards Industry 4.0: Mapping digital technologies for supply chain management-marketing integration. Business Process Management Journal.	84	28
Reischauer, G. (2018). Industry 4.0 as policy-driven discourse to institutionalize innovation systems in manufacturing. Technological Forecasting and Social Change, 132, 26-33.	82	20.5
Büchi, G., Cugno, M., & Castagnoli, R. (2020). Smart factory performance and Industry 4.0. Technological Forecasting and Social Change, 150, 119790.	77	38.5
Ayres, R. U. (1990). Technological transformations and long waves. Part I. Technological Forecasting and Social Change, 37(1), 1-37.	68	2.125

Source: Authors

3 The fourth industrial revolution: main topic in management literature

3.1 Machines and industrial internet

According to Professor Erik Brynjolfsson of MIT Sloan, data management can be considered as the modern equivalent of the microscope. Just as 400 years ago the invention of the microscope allowed to see and to measure organisms with infinitesimal precision, tomorrow we will be able to know what is happening in details and in real time, thanks to all those plants, energetic networks, engines and workplaces provided with sensors (Bonilla *et al.*, 2018). In 2012, General Electric created the term "Industrial Internet" to describe the set of the ways in which Internet can be applied to the improvement and innovation of the production processes, announcing also investments equal to 1.5 billion dollars in three years in new technologies based on sensors connected to the network, useful for the monitoring of industrial machines (Calabrese *et al.*, 2020), The aim of this initiative is obviously to enable the company to supply the technical solution and at the same time to sell monitoring software services In fact, design and post-sale services constitute today almost the half of the total income of GE; by quickly reporting, transmitting and elaborating information about the machines, it is possible to foretell and prevent malfunctions, avoiding particularly expensive post- costs. Accordingly, the application of sensors for the remote control inside jet engines helps to understand which one of the 20.000 engines in service on the aircrafts will probably need maintenance, avoiding to the airlines to spend money in non-projected interventions. Ten thousand sensors have been scattered all over the GE batteries factory in Schenectady (New York) in order to optimize productivity and to reduce product defects, discovering the causes through software analysis.

The use of sensors combined with multifunction robots is allowing many businesses to evolve rapidly. Talking to the investors in 2017, Jeff Bezos (founder and CEO of Amazon) announced that he would push to a progressive automation of the storage in the company, in order to increase the

productivity. The first remote controlled robots have begun to be more and more common in the fast-food restaurants for the production of food (Oltra-Mestre *et al.*, 2020).

However, if the placement of sensors inside the machines and the use of robots do not represent an innovation in the industrial world, the real revolution is represented by the ability to extract real time knowledge from the network of sensors, analysing them by linking different data streams (Agarwal and Brem, 2015). This new ability is beginning to offer interesting value appropriation opportunities and constitutes the base for a new kind of services (Rothwell, 1992).

In order to develop these new services, new competences are becoming crucial: the information workers are the new white collars, whose expertise span from data analysis to data visualization. It has been estimated that, only in the United States, the number of data experts necessary to meet the new demand of information workers is at least of 140.000 people, coordinated by 1.5 million of data managers.

This new information workers are employed in the most different fields, even in the traditional ones. As an example, more and more utility companies operating in the energy distribution field are making agreements with NEST, a company which acquired by Google and which became famous for its smart thermostat. In order to limit the huge expenses typical of the summer peaks, energy suppliers are creating algorithms able to turn off automatically the air conditioners of NEST users in a selective and smart way (the NEST thermostat uses the history and the weather data to foresee the temperature and it is also able to understand if the user is at home or not), Therefore, energy suppliers avoid buying expensive megawatts from the daily auctions market, producers avoid building additional plants used only during the peaks and the final user benefits from a discount on the bill, almost without noticing it.

Besides a qualified new labour force able to manage the information coming from plants, machines and devices, the ability to stipulate strategic alliances with other industrial subjects (Newcos) it is fundamental for the incumbent companies. If there will be a diffusion of a new entrepreneurial culture open to the potential of digital, automation, data crunching and data fusion and to more and more cooperative and Open innovation processes, it is highly probable that the combination between efficiency and increase in productivity introduced by the Industrial Internet will lead to an increase in the world GDP of 10-15 trillion dollar within the next twenty years (Evans and Annunziata, 2012),

The process of innovation through recombination can be easily connected to the paradigm of Open Innovation, but it needs a common digital language that enables companies to cooperate through the 5G network (Aijaz, 2020; Rao and Prasad, 2018). It is not easy to transform the language of companies, since it is embedded into each different corporate culture that makes employees to us their own internal communication codes, and speak the same language. It happens in the IT systems just as it does for people. Therefore, new ventures specialized in the creation of interfaces able to connect the companies' information systems through the creation of software "bridges" start to be common. This is the case of Apigee, a start-up established in 2004 in San Jose, California, specialized in the development of the API (Application Programming Interfaces), APIs are a software gateways that expose the information flows to the external world (and vice versa), allowing the combination of information and the production of new value. Only thanks to these "communicative joints" the various companies, allowing clusters of faraway enterprises to co-create value, could recombine information flows and re-invent their business models.

Sensors, actuators, the use of a new common language and more and more open innovation processes are the necessary ingredients for the companies to evolve and to stay competitive in the digital era (Hizam-Hanafiah and Soomro, 2021). The access to a next generation network able to satisfy the needs of every single business represents a necessary but not sufficient condition for the innovation of the Italian and European industrial system. It will also allow the research of new distribution channels and an increase in efficiency, productivity and interaction between enterprises.

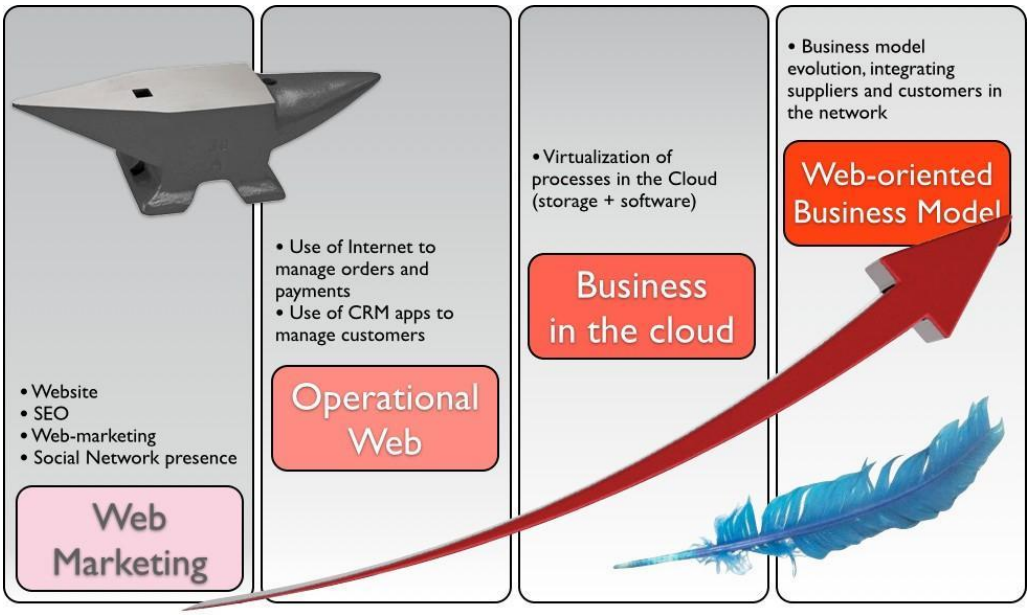
In Italy as in Europe, the SME (Small and Medium Enterprises, up to 250 employees) represent the 99% of the companies. In Italy, these enterprises produce the 70% of the total income, employing the 80% of workers8. If the diffusion of a base Internet connection in Europe is close to

the 100%, the use of the medium in the European enterprises and in particular in the Italian SME is still very low (BCG, 2018), The level of digital education of the enterprises is not high enough.

Being online does not only mean having a website, but also being able to combine and use the information provided by the network to catch new business opportunities. In the last three years, online-active enterprises have registered an increase in the incomes (+1.2%) and in the employees the 73% of the companies has employed new people against a contraction of the business for the other. An important information concerns the conditions of use of the Internet by online-active enterprises: the greatest part of companies has focused on the first phase of the innovative process. Around the 60% of them has instead focused on SEM investments (Search Engine Marketing) followed by e-mail commercials and use of social networks. Only one online-active business out of two uses virtual orders and payments.

If we put the SME in the four phases of integration of the network conceptualized in the picture, the greatest part of them would be situated between the first two steps, in which the Internet is only used as a supplementary instrument in the as-is activities of the company and as a simple showcase (Müller *et al.*, 2018; Somohano-Rodríguez *et al.*, 2020), In order to maximize the direct and indirect externalities coming from the network, the evolution which companies have to point at concerns the complete integration of the 5G network in the business, followed by the virtualization of the intangible activities and a consequent decrease in the expenses. A fourth evolutionary step sees the company changing its own business model according to the potential offered by the instrument. This will be possible thanks to the expansion of the customers' number and to a positive attitude towards the productive ecosystem, also interacting in the perspective of Open Innovation with other enterprises and discussing with the most active customers (lead users) thanks to special platforms built for this purpose. Obviously, not every company will be able to follow this path to the end, according to the field in which they operate, to their dimension or to their investment ability. However, it is important for each company to be conscious of the potential offered by the medium, in order to be able to consider the opportunity during the negotiations.

Fig. 5: The role of digital technology within the company business: an evolutionary perspective ()



Source: authors

3.2 People and Data

Electronic data constitute a plentiful resource, easy to produce (and to reproduce) and to be moved around. In every moment, billions of people contribute to generate new information, which

is continuously piled up and combined in order to generate new knowledge. This trend is impressive: the per-capita ability to store information has doubled every 40 months starting from the 80's (Hilbert and Lopez, 2011). Nowadays, it is almost impossible for an individual not to generate information: even if we do not possess electronic devices, we are in a constant interaction with them, which happens automatically or on our own will. The simple action of taking the car to go shopping to a mall is expressed into new produced and elaborated information (bar codes, points on the fidelity card, credit card payments, parking tickets, control of limited traffic zones etc.),

The new data analysis opportunities, together with the process of technological convergence, allow each individual with a smartphone to collect more and more information about the external world and about his/her own behaviour and biomedical parameters. For example, by analysing data coming from the smartphones accelerometers it is possible to estimate the kind of activity that we are doing (walking, cycling, driving) and by integrating this information with heartrate it is possible to calculate the number of calories, but also to track the distance, the gradient of the road, the number of steps and the average speed (Li, 2018).

Thanks to a sharp decrease in the cost of sensors, boosted by the mass diffusion of the smartphone, more and more new and cheap tools dedicated to the quantified self (the use of technology for the acquisition of data such as input and physical/mental performance starting from the daily life of the individual) are quickly spreading. It has been estimated that the market of smart wearable devices, which includes watches and bracelets with sensors, will reach the value of 50 billion dollars in the next 3-5 years10. It is not a coincidence that Google, Apple and Samsung have already launched specific platforms for the collection and the analysis of individual data (Google Health, Apple Health, Samsung S Health) and that they have already launched life logging devices.

A first interesting field for life logging is health and wellbeing. Today, seven adults out of ten in the United States keep their health under control. Unfortunately, it is difficult to give a scientific value to the data collected by wearable sensors, because the collection itself in not made on any scientific basis (Ayres, 1990). However, we can expect positive progresses in the next years, as mechanisms based on gamification (the use of gaming techniques in real life contexts) contribute to stimulate virtuous behaviours, making the data collection a social and funny experience. As an example, this is how the platform Nike+ works: here are directed those training data coming from the various devices possessed by the user (a bracelet, a sensor in the running shoes, a smartwatch), who is then motivated in order to achieve daily objectives that he/she can share with a community. Similar instruments are beginning to spread also in several companies in order to increase the employees' productivity and reduce the turnover. Today, we are used to asking our doctors a huge number of specific information that measure our health in a specific moment of our life: radiographies, blood or sight tests. In the future, the doctor will be able to analyse (through software) a film, a sequence of measurements more or less continuous in time, correlated and freed from the surrounding "noise" thanks to special algorithms (Ardito *et al.*, 2019).

3.3 Production and consumption

The impact of the digital economy on the real economy is strictly connected to a growing flexibility of the business models. Thanks to new methods for the production of goods and services, companies can move more dynamically in the value chain, holding new positions and discovering new markets, by evolving their business propositions. Behind the deep changes that are characterizing this historical period, it is possible to find some macro topics (Sung, 2018).

A first aspect to be considered concerns the process of servitization that has characterized numerous business activities (Frank *et al.*, 2019). The term servitization identifies an increase in the value of a good thanks to the creation of service components, often included in a bundle with the product itself. This concept, introduced in management literature by Vandermerewe and Rada (1989), expresses a continuum of solutions, in which the service component can be an appendix of the product or it can also be predominant with respect to the product component (Oliva and Kallenberg, 2003), The reasons that made traditional businesses think in this way date back to the

necessity of stabilizing and de-centring cash flows, balancing the effects connected to mature markets and to adverse economic cycles. The Broadband Internet has changed many products into services or immaterial goods. Just see what has happened in the music industry, where in a few years' time we have moved from CDs to the mp3 format to services that use a monthly subscription model such as Spotify or Apple Music. The new medium has redefined not only the format but also how we listen to music: today it is possible to rely on customized playlists or to listen to a selection of tracks created by a user on the other side of the earth. The same has happened to the film industry with Netflix and it is progressively happening in fields connected to logistics and distribution of physical convenience goods (Amazon Prime), Services can also be the incentive to stimulate the product sales, as it happens in the telephone market where the smartphone is servitized by TELCOs, in order to increase the retention rate (Baines *et al.*, 2009),

In the digital universe, software is being able to replace in a few years' time many activities carried on by previous technologies (optics, mechanics, and electronics) and to define a real new kind of language (Manovich, 2013) and new value exchange dynamics. The tendency to associate or even substitute the sale of goods with (virtual) services leads to an endless increase in the availability of catalogued resources, creating new consumption phenomena: one of these is called long tail effect. Differently from sales models that follow the Pareto rule, where the 30% of catalogued products generates the 70% of the income, the proliferation of virtual goods highlights that a consistent sales portion is composed of a multitude of niche products, each of them sold in small quantities. In 2008, the 37% of the books sales on Amazon was not composed of best sellers, but of minor titles, which in 2000 represented only the 20% of the sales (Brynjolfsson *et al.*, 2003), The same effect has been observed in the software download market. A wider availability of catalogued goods is expressed into a surplus for the consumer, and this surplus is partly re-invested, generating virtuous effects on the economy.

The concept of marketplace itself, a physical space where sales take place, has evolved and it has been replaced in many sectors by Internet platforms. Car rentals, travel agencies and assistance centres have been replaced partly or totally by online platforms such as Booking.com, Expedia, Rentalcars and Livehelp. With the spread of online and multisided selling instruments, the role of the classic commercial platform has evolved from the bazar-model (one-to-many sale) to the marketplace. Here, dematerialized goods are sold from "many" to "many" and pricing strategies move towards revenue models that, thanks to the minimum duplication and distribution costs and to a global market, play on the revenue-sharing, freemium and on try&buy mechanisms, in order to maximize the diffusion of the product in a super-populated market. Data are quite clear: the 91% of the apps downloaded from the Apple App Store and Google are free, while the 17% of the total income comes from in-app purchases. This amount will probably be tripled by 2017.

Side by side to the servitization process, a new behaviour of the consumer is gradually imposing next to new business models. Consumers are used to considering goods not only as objects that they can exercise exclusive property on, and for this reason they join new niche markets and communities oriented to the sharing ad optimization of resources, in order to generate new value with both profit and non-profit purposes. Platforms such as BlaBlaCar allow millions of European passengers to find a car lift spending less than a train ticket, and drivers to recover money to meet their travel expenses. Bookmooch allows users to share books, Airbnb to rent a room at a very low price, Couchsurfing helps the interchange of beds and Homeexchange.com to change a house with another family for the holidays.

The collaborative economy represents a new kind of socio-economic system based on trust mechanisms (such as the feedback between users) and on the fact that the value of a good can increase both for the individual and the community, if the information about that good is properly shared. Some economists, such as Jeremy Rifkin, see in the collaborative commons the natural evolution of the concept of capitalism, assuming in the next 50-100 years a gradual transition of the entire economic structure towards the new paradigm based on the sharing of common resources. It is the return to a sort of barter, empowered, enriched and made safe by the ICT (Rifkin, 2014),

While the concept of property goods is still far from a decline, it is the nature of the goods itself

that is evolving too thanks to the potential offered by the Broadband Internet. In the digital era, it is possible to produce objects with the same efficiency of the mass scale production, being also able to customize the single product, tailoring it on the needs of every single customer (Salvendy, 2001), It is a specificity called mass customization and it is now limited mainly to digital products, in which behind a general- purpose physical structure it is possible to customize the software in order to meet the demand segmentation. Mass consumption products which are highly standardized, such as smartphones or PCs, are actually different in the hands of each consumer or business thanks to the patchwork of software installed that allow different kinds of use (the Apple Watch is a clear example of a mass market product that is heavily customizable, both on the physical and on the software side),

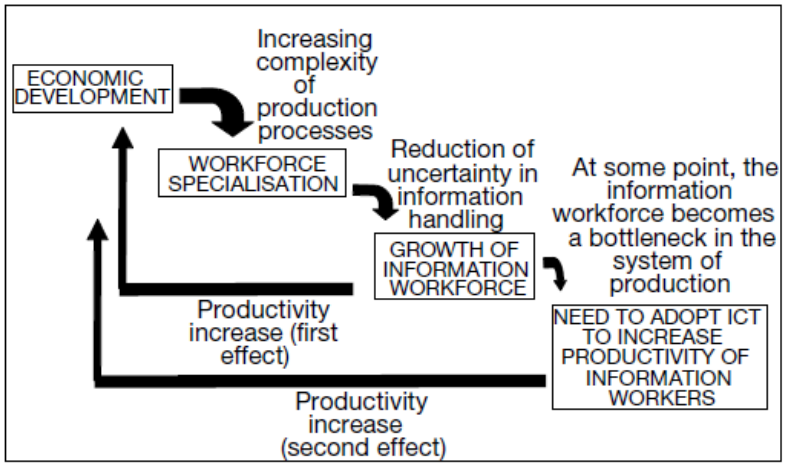
Thanks to the automation into the assembly line, even other physical properties are converging to this new principle. The automotive sector, for example, is reaching incredible flexibility levels, with robots that can be dynamically programmed and with interchangeable parts that allow the creation of different varieties of the same car without any efficiency loss. Similarly, the division of Caterpillar that is responsible for clothing and shoes can shape each shoe according to the specific feet size of each customer, thanks to robotized cutters connected to the Internet. A further technological jump will be represented by the standardization and improvement of 3D Printing techniques that will allow the use of different materials in order to build customized objects, subverting the production of physical goods.

3.4 Employment in the digital era

Commonly, the image of the robot that substitutes the worker in the assembly line represents the most evident effect of a digitalization that, together with the mechanization, the evolution of the automation industry and the use of the Internet, has allowed enterprises to innovate their own productive processes. In order to understand the deep effects of the Broadband Internet on occupation, it is necessary to think about some dynamics that connect technological innovation to work (Neumann *et al.*, 2021),

Concerning occupation, society is moving towards what is commonly known as information society (Porat, 1976). Today in Europe more than the 50% of the labour force is composed of information workers, who elaborate, transfer or produce information. The relation between economic development, ICT technologies and increase in the number of information workers can be explained according to Katz's graph (Katz, 2009),

Fig. 6: ICT diffusion and growth of information workers: causality model (Katz, 2009),



Source: Katz, 2009

At first, the economic development leads to an increase in the complexity of the production processes, which require a specialized labour force. Thus, enterprises look for employees able to

handle information correctly in order to manage goods production and service supply. Then, the growth of the information workers becomes a bottleneck for the system: their number cannot increase endlessly (Ślusarczyk, 2018). Furthermore, the increase in the complexity of the information itself constitutes a second issue. This makes enterprises innovate their own technologies (and their business models), adopting solutions that increase the productivity of the labour force and making the elaboration of information easier. Therefore, it is possible to face both problems and the virtuous circle of economic growth is nourished.

The evolution of the Broadband Internet and its multiple applications in the industrial field (Industrial Internet) enter this process as a condition sine qua non, where technology is at the same time object of innovation and engine for the industrial innovation. Here, workers are asked to be skilled in the manipulation of information flows and to be constantly updated about the evolution of their own competence.

What will the impact on the labour force be? The achievement of a positive balance (occupational growth) appears again strictly connected to the penetration of the Broadband Internet. The more penetration grows, the more enterprises find a benefit in the multiple technological applications. Thinking about the adoption of technologies based on the Broadband Internet only as a way to increase the efficiency of the productive processes (with a negative effect on occupation) can only constitute a short-term reaction, often conditioned by the macro-economic situation. Growth has to be the medium/long-term objective, together with the ability of the enterprise to leverage on technologies to innovate its business processes (Chesbrough *et al.,* 2003), Only the companies that are able to fully exploit the benefits offered by the new technologies will consider the IT instrument as a resource, and not as a commodity, innovating in order to grow, differentiate and consequently increasing the labour force in the medium/long-term.

In addition to an "evolutionary" process concerning incumbent companies, many new entrepreneurial realities are obviously "native digital". Here, new professional figures will be employed. Part of the remaining labour force could also be absorbed by new companies that could act as outsourcers, thanks to the possibility of carrying out remote services for other enterprises. Where will these enterprises be? In addition to some considerations concerning taxation and labour costs, a necessary condition will be the availability and a guaranteed quality of the IT infrastructure.

A first study carried out by Fornefeld has summarized and quantified the different components that have an impact on occupation (see picture), showing some empirical results based on case studies (Fornefeld *et al.*, 2008), It is a synthesis and quantification attempt, which paves the way to further and necessary researches on the subject. In addition to some evaluations on the redistribution of the labour force23, it is also important to think about the new work methods that characterize more and more the information workers. Where will the information workers operate? Technology has a direct impact on labor. Since the 80's, digital technologies have overbearingly entered companies, bringing efficiency and a progressive de- materialization of a growing number of activities. Then, Internet started to allow companies to be spread on the territory and to share information thanks to the access to common databases. In the 90's, customers and suppliers started a telematic communication with companies, allowing producers to improve the supply chain and the distribution channels, and buyers to purchase products without the presence of a sales network located in the territory. With the development of strong broadband networks and the mobile connection, the process is now accelerated. The role of the employee is evolving accordingly: many tasks that do not require physical interaction with machines or people can now be completed from everywhere, far beyond the physical collocation of the company. It is the so- called telework, or remote work, a new common practice able to bring substantial benefits both to the company and to the worker.

Thanks to the telework, companies can save on fixed costs, re-shaping the volumes of their physical structures. The presence of hot desking is more and more common. These are a sort of workspaces that can occasionally be reserved by the worker who needs to go to the main office. This has to be added to a series of improvements connected to transports from/to the main office (and consequent paybacks) that increase the wellbeing of the worker, who can save time, and have a

positive impact on the environment. Only in the USA, savings in terms of gasoline (responsible for the greenhouse effect) due to non-displacements account for 247 million tons of CO2 emissions.

According to a U.S. based survey, the 41% of the workers declares that there are different activities in their job that could easily be carried out from home, as they do not require the physical presence in the office25. In this sense, telework is considered as a forefront instrument, able to have a positive impact on the image of the company itself, and as an engine for an increase in productivity. Totally, between those workers who think telework is possible, the 68% would take into consideration a flexible job (1-2 days a week) and the 58% a full-time telework.

Some problems in this new practice, which leads to a dispersion of the employees, concern the development of the employee's career and the impact on the organizational structure of the company itself, together with a greater difficulty in transmitting the company values (employer branding activity) and the necessity of increasing data protection.

In order to support this social evolution, it will be essential to develop a new digital culture for the organization of the company, together with new tools and specific investments aimed at increasing the safety of Broadband Internet networks.

4. Future trends and trajectories

The economic and social benefits of the digital economy are numerous and they have a pervasive impact on many aspects rule the life of people, enterprises and Countries. In the previous sections, some key topics have been analysed and the way in which new technologies can play a leading role for the society's virtuous development has been pointed out. In order to maximize these benefits, it is necessary to focus on the elimination of technological obstacles to digital innovation, focusing on problems that can corrupt the efficiency of the technological innovation by producing negative relapses, if underestimated. In this section, we are going to show some directions for further research on the topic.

4.1 Safety

An entire pillar of the European Digital Agenda is dedicated to the networks' safety. With the virtualization of the greatest part of the economy and the dependence of the totality of services to people and enterprises on the Internet, it is fundamental to protect networks from new kinds of criminals, who operates from home and who are experts in breaking firewalls and opening bugs in the informative systems (Reniers, 2017), The so-called cyberattacks concern both privates and enterprises, especially those operating in sectors with a high content of intellectual property. Last year the number of business cyberattacks had a growth of the 14%, in comparison to the previous year, with peaks of the 600% in sectors such as pharmacology, chemistry, agriculture and mining, and of the 400% in the oil & gas sector.

If systems cannot guarantee a proper safety level and data protection, the entire digital innovation produced by the Broadband Internet will come to the standstill, with a consequent unsuccessful use of the systems and waste of resources. CISO (Chief Information Security Officers) highlight alarmingly that only the expenses for the protection of the IT systems constitute the 20-30% of the investments, slowing down innovation. The old protection measures were implemented when the companies' servers collected the whole information, but now they are not enough anymore, as the information technology perimeter has enlarged with the adoption of the BYOD (Bring Your Own Device) and of cloud solutions.

The lack of competences in the companies to face the topic is even more alarming: this leads numerous enterprises to invest blindly and in complete solitude. As the safety level of a network is equal to the lowest safety level offered by its knots and as systems are more and more connected and technologically complex, the problem of cyber security has to be tackled from a different perspective (Xu et al., 2018).

It has to be faced not from the single company point of view but by taskforce that reunites technology suppliers, regulators, agencies in charge of controls and fees, connectivity suppliers and the representatives of the various companies. Only if precise responsibilities and roles are detected by the policy maker it will be possible to prevent thefts and violations in the data domain. Only if platforms could be strong enough and safe from unwelcomed intrusions, companies will use the new cloud systems and the virtuous benefits mentioned in the previous sections will see the light. McKinsey esteems that the global economic value fluctuation, depending on the networks level of strength, will vary between 9 and 21 trillion Dollars in the period 2014-2020.

4.2 Digital Identity, privacy and data traceability

A second delicate topic concerns the management of the digital identity, which is the combination of those modalities introduced to recognize properly who carries out operations and produces and diffuses the contents in the networks. The digital identity is a multi-level concept that has to guarantee a reliability level coherent with the context in which it is used (Trantopoulos et al., 2017). At the level of maximum security, it can be a sort of virtual identity card, which can be used in order to certify the numerous activities that individuals and companies carry out online. The topic of the digital identity is tightly connected to the topics of the necessary authentication to gain access to online services, of the authorization to carry out operations, of the digital counterpart, of eventual delegation mechanisms and of people's privacy. In an era in which is impossible not to leave a digital footprint, it is fundamental to understand which is the level of "stickiness" of the digital identity, and which information is shared (and how long) with the many entities along the networks' value chain.

The safeguard of the digital identity is a complex topic, as it introduces a requirement that contrasts with one of the paradigms of the digital revolution: the possibility to recombine bits and to copy data freely. This paradigm conflicts with the necessity to certify an individual univocally, without the possibility of duplication or identity cloning (Khan *et al.*, 2017). If this adds to the complications connected to safety explained in the previous paragraph, what comes out is a particularly tangled situation, both from a technological standardization point of view and from an ethical and legal one. While it is easy to control accesses to physical spaces and people's identity, the greatest part of online platforms (including Google and Facebook) draw ID without any formal mechanism that can guarantee the identity of the user in front of the display. The development of instruments such as OpenID Connect or Mobile Connect, based on the connection of the virtual identity to goods and services is in progress, in order to face these phenomena. However, what is happening today is that each supplier uses its own internal mechanisms to authenticate users' identities, with the indirect complicity of the lack of a shared and compulsory standard. This calls for the need of global policies on the topic.

Data tracking is another topic directly connected to the digital identity and consists of technologies that allow univocally the control of the information flows, in order to trace the chain behind every single operation and to favour the cooperation between multiple users on data streams. Data tracking is put into practice with protocols of data enrichment and with tool software that allow the rapid visualization of who had access to the information and when. Even if far from a standardization, data tracking protocols will soon be a key element, part of the semantic evolution necessary to the Broadband Internet in order to simplify and innovate the processes which enterprises and citizens are subjected to.

4.3 A new concept of city

Besides having an impact on economy and innovating the way in which enterprises and workers operate, the Broadband Internet becomes a fundamental element for the governance of the city itself (Nick *et al.*, 2018),

"The nineteenth century was a century of empires. The twentieth, a century of nation-states. The twenty-first will be the century of cities". With these words, the mayor of Denver Wellington Webb talked to the audience during the American mayors' conference. The current socio-economic evolution is leading to a progressive centralization of the national and supranational government in the role of policy maker and to an opposite de-centralization of the executive efficacy, linked to the current globalization process. Thanks to this evolution, many medium and large cities have become the real knots of the productive, social and economic network of the various countries, which are constantly looking for new solutions to face the numerous problems connected to the services management and the public facilities. The digital revolution is obviously one of the factors that have favoured the evolution of the city from outskirt of power to autonomous subject, able to innovate (Campbell, 2012), Thanks to new instruments enabled by the Broadband Internet, contamination processes between different cities will allow a more and more frequent interchange of best practices and knowledge between close and distant cities. This virtuous contamination is essential in order to guarantee an inclusive growth and to start joint innovation practices.

Today, the smart city has to be seen as an urban space ruled by a farsighted local policy. With the help of digital technologies it tackles the challenges of globalization and economic crisis with an attention to social cohesion, to the diffusion and availability of knowledge, to freedom and direct access mobility, to the quality of the natural and cultural environment (Niger, 2012), Thanks to the Internet, cities are not alone, but are inserted in a network of peers where they can share competences, best- practices and talents, where innovation becomes viral and is adapted according to the local specificities (Gurjanov, *et al.*, 2020; Nick *et al.*, 2019), As it is confirmed by Johannes Hahn, member of the European Commission and head of the office for the Regional Policies, "looking beyond and developing the ideas of tomorrow's cities has become important at any level. The development of the city will determine the development of Europe". These are cities with a digital and connected nervous system and they find in technology an instrument able to reconfigure the existent attraction mechanisms towards companies and citizens. In the following paragraphs, three examples of sectors where cities can invest to gain attractiveness are presented. In the next years, Europe could point at these sectors (among many others), which see cities in the front row as engines for creating a better future, more participated, inclusive and fair.

4.4 Sustainable mobility

The growing concentration of the population has brought to a relentless and progressive saturation of the urban road network that, especially in the European capital cities, had been planned at the time of chariots. City planners have now to reorganize infrastructures and find new ways for the management of urban flows, mixing the concept of property and sharing, in order to maximize the efficiency and to reduce the environmental impact.

New digital instruments are a valid allied for the management of people and goods flows: they allow the precise and real-time monitoring of the traffic situation, the management of car parks and openings and the creation of Limited Traffic Areas. Furthermore, they can help to fine trespassers electronically, to intervene quickly in case of emergency and to optimize the frequency of the public transports and the traffic lights intervals according to the specific moment of the day, favouring the flow of vehicles (Alptekin *et al.*, 2020), However, the challenge is much more complicated, and it includes a complete re- mapping of the mobility infrastructure, including digital nerves inside the viability, transports and logistic systems. It is a complex process, which requires a long-term vision and the development of new private-public partnership. However, to see everything in watertight compartments and connecting many electronic systems without an overview, can produce the opposite effect, increasing the informative entropy, complicating people's lives and forcing them to move between different "silos". For this reason, in a city/platform it is fundamental for data to be more and more open and shared, always respecting people's privacy. In addition, each system has to be built according to a modularity defined beforehand, in which data can be produced and managed respecting common standards (Frank et al., 2019).

Next to a top-down approach, in which data collection is planned, operated and ruled by a public corporation, it is possible to find a bottom-up modality. Why would someone invest in the improvement of the road network by putting sensors on traffic lights when every driver possesses a smartphone full of every kind of sensors? Services such Google Maps already work in this way, locating weak points and car crashes and estimating the distance time according to data coming from private devices. Uber leverages on smartphones' GPS signal to connect passengers with drivers.

In addition to humans carrying a connected phone, vehicles can also be moving sensors, able to transmit traffic, temperature, road surface and traffic lights data using the smartphone as a hub to receive and send information.

The evolution of urban mobility will be also complemented with the introduction of the automatic guided vehicles, such as the Self Driving Cars. The combination of precise satellite location services, the deployment of 5G low-latency networks and the improvements in computational capabilities and LIDAR systems are the technological bricks that will support the development of this sector, which has quickly taken a curtain talk in the last few months. An ubiquitous broadband connectivity and the ability to split the computing load between on board local processing and remote elaboration in the "cloud" will be the possible discriminating factors for the future market success or failure of this category of products and services.

5. Conclusions

The fourth industrial revolution is leading to fully automated and interconnected industrial production. The new digital technologies will have a profound impact in the context of four development guidelines: the first concerns the use of data, computing power and connectivity, and is divided into big data, open data, Internet of Things, machine- to-machine and cloud computing for information centralization and storage (Del Sarto *et al*., 2021). The second is that of analytics: once the data has been collected, it is necessary to derive value from it. Today only 1% of the data collected is used by companies, which could instead obtain advantages starting from "machine learning", that is, from machines that improve their performance by "learning" from the data gradually collected and analyzed. The third direction of development is the interaction between man and machine, which involves "touch" interfaces, increasingly widespread, and augmented reality. Finally, there is the whole sector that deals with the transition from digital to "real" and which includes additive manufacturing, 3D printing, robotics, communications, machine-to-machine interactions and new technologies for storing and using energy in a targeted way, rationalizing costs and optimizing performance (Reischauer, 2018).

In the coming years, technological and demographic factors will profoundly influence the evolution of the labor market. Some (like cloud technology and flexibilisation of work) are influencing the dynamics right now and will do so even more in the next 2-3 years. The effect will be the creation of 2 million new jobs, but 7 will disappear at the same time, with a net negative balance of over 5 million jobs. Italy comes out with a draw (200,000 jobs created and as many lost), better than other countries such as France and Germany. At the level of professional groups, the losses will be concentrated in the administrative and production areas: respectively 4.8 and 1.6 million jobs destroyed. According to the research, the financial area, management, information technology and engineering will partially offset these losses.

The 4.0 Factory, daughter of the fourth industrial revolution, is made up of machines that are completely interconnected with each other, which communicate with each other and carry out self-diagnostics and preventive maintenance (Büchi et al., 2020). In particular, the maintenance of machinery by the machinery itself, thanks to the IoT, will exceed that of humans in quality, capacity and speed. Advances in technological evolution will lead factories to autonomously predict the degree of production failure, to adopt the best prevention measures and to implement self-repairing actions. Furthermore, as explained in Industry 4.0. Men and machines in the digital factory, in

Factory 4.0 the flexibility of the plants will be such as to allow the products to be customized according to the individual customer. Robots will work in contact with humans and from humans they will learn in a natural way. The workflow can be reproduced in a virtual way, therefore before physically preparing it in the workshop, to verify its behavior in the abstract and enhance its performance. The factory will know how to procure energy without waste and at the lowest possible cost, in a word it will be smart.

With this paper we identified trend and trajectories that could be useful for managers dealing with such a revolution. In particular we aim at providing them "food for thought" and inspiration to rethink their managerial style within such an emerging landscape. By conducting a state-of-the-art review of the literature, it extends our understanding of Industry 4.0 and identifies four main relevant topics in management literature related to the fourth industrial revolution: 1) machines and industrial internet; 2) people and data; 3) production and consumption; and 4) employment in the digital era. Furthermore, it reveals the contours of a fragmented landscape that raises four major intriguing avenues for future industry 4.0 inquiry: 1) safety; 2) digital identity, privacy and traceability; 3) a new concept of city; and 4) sustainable mobility.

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