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COLLABORATIVE DIGITAL SHIFT TOWARDS A NEW FRAMEWORK FOR INDUSTRY AND EDUCATION

Handbook for Industry

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Introduction

The fourth industrial revolution is bringing significant changes in working life and private companies' operations. To be able to benefit from the technological shift towards the digitalized world, companies need to find their path in taking on three new significant challenges. The first of them is a lack of a skilled workforce that understands new technologies and knows how to make strategic use of information. The second is a lack of knowledge on how to identify future work issues and solutions to address them. And finally, lack of vision and strategy for choosing the proper technology and building system integrating environment.

Higher education institutions can support companies in taking on the challenges, providing a skilled workforce and constant training. Moreover, not only is the cooperation mutually beneficial, as the industry can deliver market insights, it also provides support, innovation, and economic development for local societies through social programs.

The handbook was created to briefly present Industry 4.0 and its potential benefits. Moreover, it promotes sincere cooperation between the Industry and Higher Education Institutions. The recipients of this publication are executives in companies that want to be a conscious subject of the Industry 4.0 revolution.

In Chapter 1, the handbook presents the benefits a company can obtain through Industry 4.0. The chapter also briefly presents tools developed by companies and researchers that can be used to estimate a referential Industry 4.0 level and to monitor its development. Chapter 2 describes incentives to cooperate with universities in creating new fields of education, especially when new professions emerge. Finally, Chapter 3 contains recommendations worked out during the workshops organized as part of the Universities of Future project. It also sketches out the risks of new solutions and their confrontation with the effects of the COVID-19 pandemic.

Marcin Luckner, Assistant Professor, Warsaw University of Technology

Industry 4.0

1 Industry 4.0

1.1 Industry 4.0: state of affairs

Industry 4.0, which is called the fourth industrial revolution, refers to the concept of a factory system that wirelessly connects machines and related sensors into a system that can visualize the entire production line and make decisions on its own [1].

For a better understanding of this concept, the researchers analyzed scientific literature from the years 2015-2019 that referred to “Industry 4.0” or “Industrial revolution 4.0” [2]. The study was limited to the construction industry but allowed the authors to define three main semantics groups that can be generalized for the whole Industry: Technology, Security, and Management

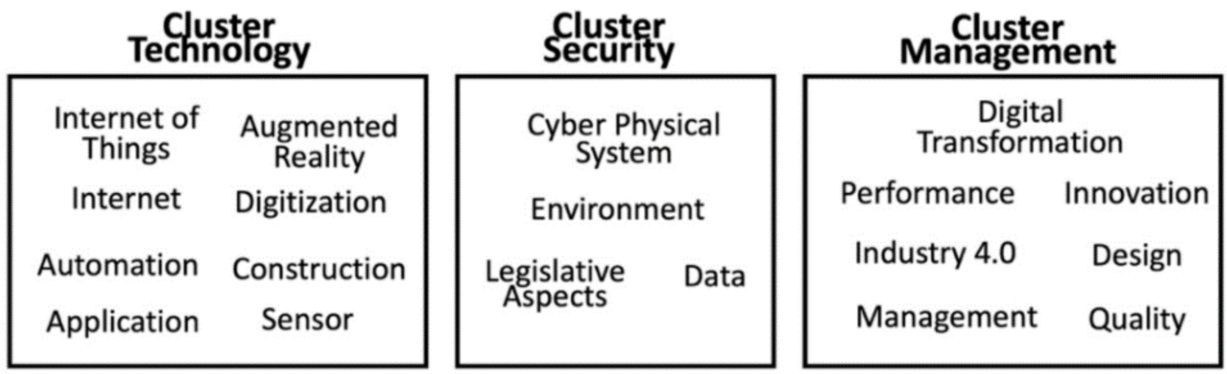

Figure 1 Topics related with Industry 4.0 [2]

This categorization shows that Industry 4.0 covers all possible business aspects. It starts with Technology by automation, sensors, and digitalization. That leads us to the Security related to the protection of data and interfaces of cyber-physical systems. Finally, the changes involved by Technology must be accompanied by a Management strategy to supervise the quality of the introduced innovations and new designs.

The complexity of the new revolution has been stressed before. Industry 4.0 technologies have been found to be far-reaching despite their maturity and availability. Their impact embraces political, economic, social, technological, environmental, and legal challenges [3]. It has also been emphasized that Industry 4.0 technologies influence technical, organizational, and geographical dimensions by the globalization of its major processes, routines, and procedures [4].

Today, Industry 4.0 is not a theoretical concept anymore. It is applied in an automated mass production [5] and manufacturing [6] and its social aspect can be observed [7].


INDUSTRY
4.0

1.2 Benefits

The development of Industry 4.0 in a company brings a series of technological benefits that can, nonetheless, have a more revolutionary rather than evolutionary character, and are not limited to machines. The obtained benefits concern aspects such as production, management, human resources, support, and cooperation with a social environment.

1.2.1 Improved Efficiency

Improved productivity translates into less machine downtime and the capability to make more products faster.

Real-time data collecting helps to facilitate the business decision-making process, improve the quality, and speed the process of identifying the areas for tuning in ongoing productions.

1.2.2 Increased Knowledge Sharing and Collaborative Working

Traditional manufacturing plants are process-based and operate in silos. Individual facilities work as separate machines. This separatism results in minimal collaboration or knowledge sharing.

Industry 4.0 technologies such as digitalization allow production lines, business processes, and departments to communicate regardless of location, time zone, platform, or another factor.

Implementing Industry 4.0 technologies enhances the capacity to automate the process, i.e. machine-to-machine and system-to-system, with minimal human intervention.

1.2.3 Flexibility and Agility

The benefits of Industry 4.0 also include enhanced flexibility and agility. It will be easier to scale the production up or down in the Smart Factory. It is also easier to introduce new products to the production line as well as create opportunities for one-off manufacturing runs, high-mix manufacturing, and others.

1.2.4 Easier Compliance

Complying with various and frequently changed directives in highly regulated industries can be more time-efficient and can even be automated. Industry 4.0 can technologies automate compliance, including track and trace, quality inspections, serialization, data logging, and others.

1.2.5 Enhanced Customer Experience

Industry 4.0 technologies create more opportunities to improve the service offered to customers and customer experience. That means improved responsiveness, deeper insights with real-time availability, and automated customer service.

Faster problem identification leads to a quicker emergency system response. Process digitalization and data analysis minimize issues with product availability and quality improvements. Together, the gains have a direct effect on profitability.

1.2.6 Cost Reduction

Industry 4.0 technologies implementation should be considered a long-term investment as it delivers easily calculated ROI's.

Cost reduction drivers:

- better use of resources,
- faster manufacturing,
- less machine and production line downtime,
- fewer quality issues with products,
- less resource, material, and product waste,
- lower overall operating costs.

1.2.7 Innovation Opportunities

Industry 4.0 technologies give more profound knowledge of the manufacturing process, supply chains, distribution chains, business performance, and even manufacturing the products. New forms of cooperation established with HEIs and governments create professional and functional development opportunities that can result in innovations addressed to the general company performance.

1.2.8 HR Challenges and Employer Branding Programs

Companies with developed high-tech data-driven environments will encounter fewer issues in recruiting and retaining the white-collar employees that will become the majority among the total workforce. The increasing employment of college graduate workers shows that a new labour market structure has been constituted. The demand for and supply of white-collar labour is higher than in competitive markets, reaching over 55 percent already in 2007 [8].

The cooperation between industry and HEIs can help in adjusting their culture, organizational aspects, leadership styles, and skills to a new mindset necessary to meet the digital era demands. The cooperation also creating of re-skilling and upskilling training opportunities.

The younger workforce, especially in engineering, is accustomed to using technologies and expects their employers to follow the latest trends associated with the digital era. The new approach affects engineering, business, and design competencies, which companies will have to improve to attract and retain the workforce.

1.2.9 Corporate Social Responsibility

Cooperation between HEIs and industry can be organized based on Corporate Social Responsibility (abbrev. CSR) with its social reference. The social commitment of both companies and HEI's could be linked and jointly used for regional economic development, an increase in the level of innovation, and the level of educational development in society. Companies and HEI's can implement programs designed to resolve environmental, social, and ethical challenges that will also have a beneficial effect on their economic performance.

1.3 Assessment of Industry 4.0 development

1.3.1 Industry 4.0 development in various branches

The Capgemini report [9] assesses Industry 4.0 maturity according to two factors. The first factor – digital intensity – describes how far the essential business processes were digitized and how much digital technologies are present in the industry. The second factor – transformation management – shows how well the transformation is being managed.

Figure 2 Digital Maturity Matrix by Industry [9]

Figure 2 shows the digital maturity matrix for selected branches. The trades at the beginning of the journey are Pharmaceuticals and Manufacturing. The highly-developed digitalization section includes Travel and Hospitality. Their essential process as booking and reservations have been digitalized. Meanwhile, Insurance leads the way in transformation management. This trade has the necessary governance and digital competencies for digitalization. Finally, Banking and High Technology are digital masters. They mastered both digitalization aspects.

1.3.2 Industry 4.0 Maturity Index

Another assessment method proposed [10] is the Industry 4.0 Maturity Index. The authors define capability stages that lead to Industry 4.0. Figure 3 presents the following six phases.

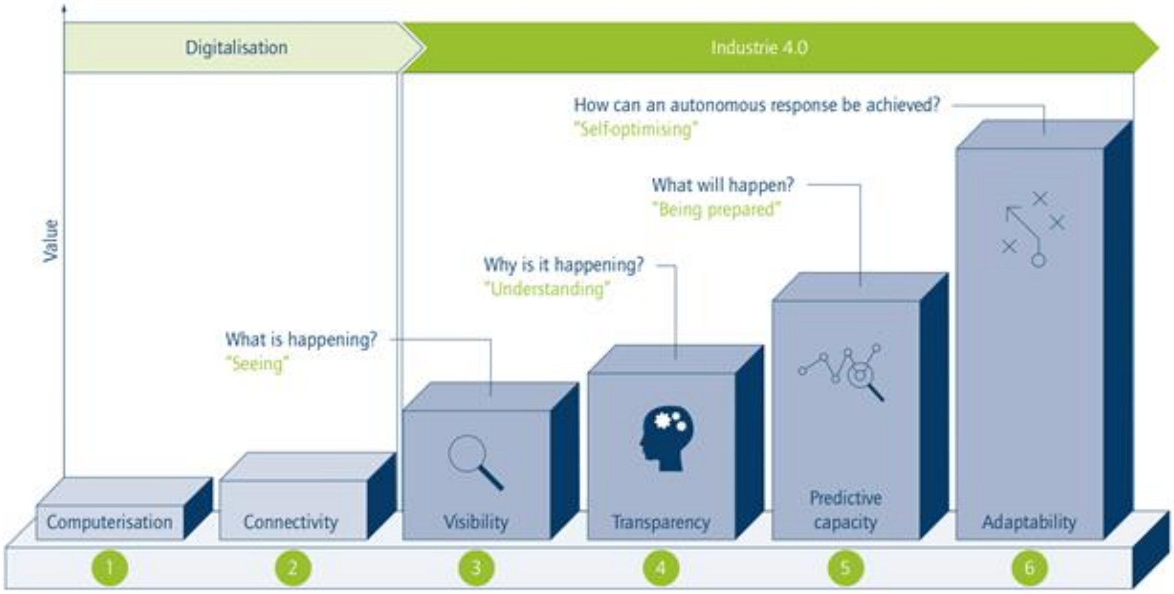

Figure 3 Stages in the Industry 4.0 development path [10]

The first ones are Computerization & Connectivity. Computerization supports business processes digitally and shared platforms replace isolated applications. The following stages are Visibility & Transparency. Gathering distributed real-time data together, a company increases visibility when information about the processes becomes available and more exhaustive. A created transparency enables understanding of the production process. The next stage is Predictive Power. The collected historical data merged with incoming real-time stem data allows the company to anticipate the future based on a likelihood. A created projection increases decision quality. Adaptability & Self-Learning are the last stages of the process. The previously created decision system takes over some decisions that diverge from an initial business strategy. The prediction adapts to a changing business environment. Based on past feedback on specific events and their respective outcomes, the systems learn and further improve their decisions.

1.3.3 Industry 4.0 Digital Compass

For discussion of an application of Industry 4.0 in various business aspects, the McKinsey company created a tool called the McKinsey Digital Compass that maps Industry 4.0 [11]. The compass – presented in Figure 4 – defines eight main value drivers.

Figure 4 McKinsey Digital Compass [11]

The first driver is Labor as an essential cost driver in most industries. The cost can be reduced with Industry 4.0 by automation of production and automation of knowledge work through breakthrough advances in artificial intelligence and machine learning. The second driver is Inventories as a risk of tying up capital. The risk can be decreased by pre-modeling using in situ 3D printing. Quality is the primary driver because rework of invalid products leads to extra costs. It can be managed by Advanced Process Control (APC) and Statistical Process Control (SPC). Supply/demand match is the driver since an understanding of the customer demand maximizes the value captured from the market. Industry 4.0 introduces a data-driven design to value and demand prediction. Time to market becomes the driver because reaching the market with an innovative product earlier creates additional value. The new tools that support market observation are rapid simulation, concurrent engineering, and customer co-creation innovation. Service costs, which are an essential part of operation costs, can be reduced when the after-sales services are operated through predictive and remote maintenance and visually guided self-service. The next driver, resource process, generates waste that can be reduced using real-time yield optimization and smart energy consumption. The final driver is Asset utilization. A mapping of the physical process lifecycle onto the digital sphere allows the companies predictive maintenance and real-time process optimization. Observation of all eight mentioned drivers and applied managing tools enable us to assess how completely Industry 4.0 tools were introduced in the company.

1.3.4 Industry 4.0 Radar chart

A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises was proposed by academic authors in [12]. The authors summarized several previous models and introduced a new one using nine dimensions: Strategy, Leadership, Customers, Products, Operations, Culture, People, Governance, and Technology. Using a survey that assesses each of these dimensions in 1-5 rank, it is possible to prepare a radar chart visualizing Industry 4.0 maturity. Moreover, the assessment can be used to develop a roadmap for future improvement. The radar is presented in Figure 5.

Figure 5 Radar chart visualizing Industry 4.0 maturity in nine dimensions [12]

Industry and Education 4.0

2 Industry and Education 4.0

2.1 Needs

The impact of Industry 4.0 is significant not only for business but for the whole society. Progressive automation eliminates workers from the market, as robots, algorithms, or automation can replace them. However, this phenomenon is no longer limited to physical workers; it also touches white-collar workers. The automatization spreads throughout more and more management and optimization processes (resource management, energy consumption forecasting, workers schedule optimalization). Developing automatic programming may reduce the need for programmers in the labor market by automatizing software refactoring and evolution [13]. New employees' traits and skills will be sought and necessary. Therefore, changes must happen both in the industry and the education process.

The changes in the work organization – smaller teams, remote work, and international cooperation, forces industry and higher education institutions (HEI) units to rethink priorities in their educational offerings. On the other hand, running technical and computational development together with a deluge of data forces companies to look for competitiveness through cooperation with academic research centers in innovative projects.

2.2 Cooperation with HEI

Some HEI centers are highly interested in cooperation with business and education Industry 4.0 specialists. The universities create their programs and units dedicated to interacting with the business. There are also international networks that unite innovative HEI hubs.

2.2.1 Individual Academic Programs

The Warsaw University of Technology has undertaken several initiatives to promote collaboration with industry. The following examples highlight the successful projects and their results. The university, as well as separate faculties, established a board consisting of members of industry interested in the education of current students, their potential employees. A consultation with the board showed that the alumni have fundamental knowledge and professional competence. However, they lack soft skills essential in Industry 4.0, such as teamwork and communication.

Figure 6 Creative space at Centre for Innovation and Technology Transfer Management of Warsaw University of Technology (CZIiTT PW)

To address this, the Warsaw University of Technology Rector established INFOX WUT's Creativity Booster. The new unit recruited and trained academic teachers that started interdisciplinary projects for WUT students, drawing on the experience of international educational centers. Additionally, a special space for creative teamwork was created.

The projects conducted by INFOX and hosted by DRIMn (Department of Innovation Development of Young Scientists, located in CZIiTT) aim to teach cooperation and communication within the team and with clients. To reach this aim, the students work with business partners. There are also dedicated courses at selected faculties that focus on students specializing in fields such as IT. Specifically, one of the courses led by WUT was Forge for Industry 4.0 Leaders. The program was addressed to future candidates of the Masovian Centre for Industry 4.0 Competence. The program includes activities (workshops, meetings, trainings) aimed at educating and shaping the engineers of the future, Industry 4.0 staff. In a course that applies the Design Thinking (DT) methodology, students learn about tools and technologies related to Industry 4.0, which they will use to solve a problem proposed by the Ministry of Economic Development. The program was created to better adapt the future leaders to the changing conditions of business, as well as to train them to perform tasks related to the preparation of activities for the industrial transformation in Poland [14].

The center has earned an excellent reputation and is now part of the international networks SUGAR and DFGN.

2.2.2 SUGAR

SUGAR is a global network that brings together universities and companies for the future of innovation through a new learning experience. Students, supervised by trained academic teachers, form intercultural, multidisciplinary teams, and work together on exciting design challenges provided by corporate partners. For nine months, the students work alongside companies to develop a project that results in a high-fidelity prototype.

The SUGAR Network, established in 2008, joins 24 leading universities all over the world.

One of the projects conducted by the SUGAR Network partners is ME310 [15]. Students in ME310 take on real-world design challenges brought forth by corporate partners. In many academic engineering projects, students work on a separated and isolated part of the system. In ME310, the students must design a complete system while being mindful of not only the primary function but also the usability, desirability, and societal implications. Throughout nine months, the students prepare and test many of their design concepts and in the end, create a high-fidelity prototype that demonstrates their ideas.

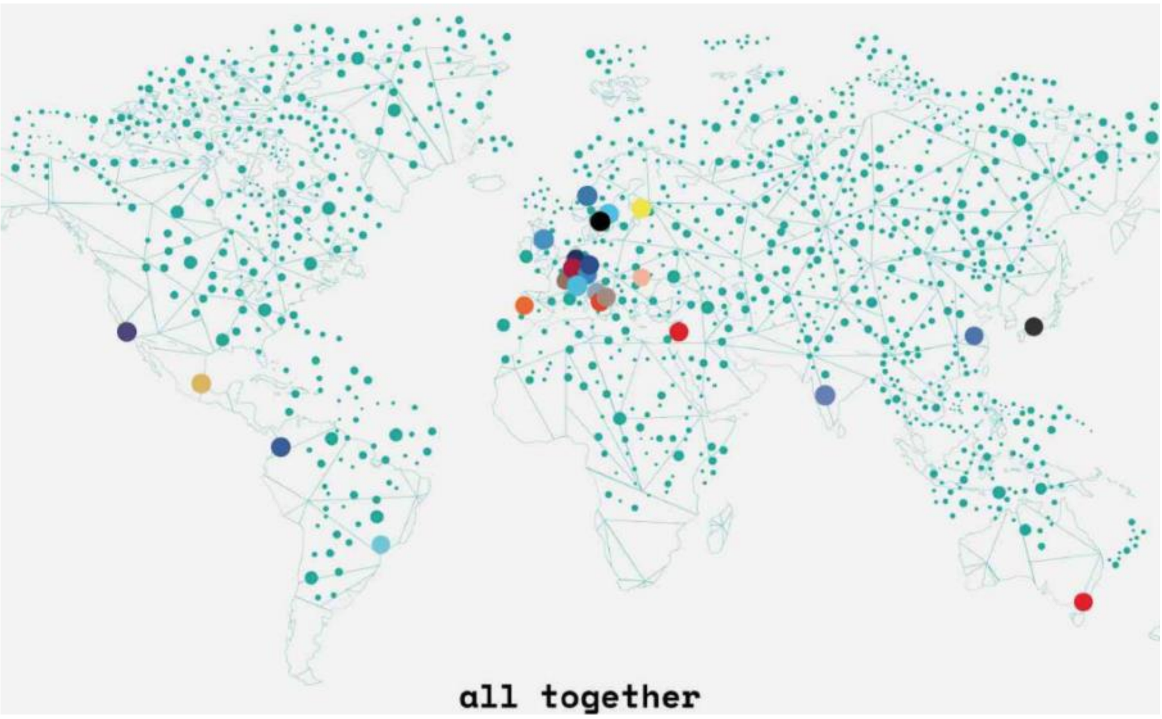

Figure 7 SUGAR Network [16]

2.2.3 Design Factory Global Network

Design Factory Global Network (DFGN) is a network of innovation hubs in universities and research organizations. The network is on a mission to create change in the world of learning and research through passion-based culture and practical problem-solving. The Design Factories united in the system collaborate efficiently across cultures, time zones, and organizational boundaries fostering radical innovations. The roots of DFGN are located in Aalto Design Factory.

DFGN extends to almost all corners of the world with partners in five continents. All twenty-three Design Factories are created to drive change in the local context, whether a university or a research institution host it.

The DFGN partners conduct, among others, Product Development Project (PdP) [17], the course is aimed at master students in technology, business, and design). However, the course is also open for other students from various master's studies, e.g. cognitive science, anthropology, and biology.

The course follows a problem-based learning (PBL) methodology. The challenges are given and sponsored by industry partners, who are searching for innovative cooperation with the next generation of product developers.

The supervising academic teachers' attention is directed to the forming of highly motivated interdisciplinary teams. A project typically includes phases of understanding the challenge, planning, research, concept generation, prototyping, and testing. The project concludes with a presentation of the final functional prototypes of a tangible product or service solution for their industry challenge.

Figure 8 Selected Design Factories united in the network [18]

2.2.4 National and International Cooperation Programs

In many countries, national research and development centers support research units and enterprises in developing their abilities to create and apply solutions based on scientific research results. The centers give grants to academic groups and business cooperation to encourage economic development and the benefit of society.

Usually, the center is also a contact point that provides information about the current program offer. The contact point supports clients in preparing research and development projects and provides information about the documentation required in specific calls, and the national programs supporting R&D activities.

Additionally, there are international programs. Horizon 2020 [19] is the most significant European Union Research and Innovation program with nearly €80 billion of funding available over seven years.

Horizon 2020 aims to make Europe a more attractive location for small and large businesses supporting the development of technology innovation across a range of sectors. The program supports public-private partnerships and simplifies granting procedures.

2.3 Industry benefits

Industry 4.0 offers a unique opportunity to redesign SME production processes and adopt new business models [20]. In the information age, any information brings measurable, monetary profit, which is why Big Data solutions are indisputably appropriate. Continuous information about the state of devices and systems obtained from a network of sensors also brings measurable gains via a better understanding of the production process. This allows analytics specialists and managers to simulate and optimize the production process using modern algorithms, bringing financial benefits. Moreover, understanding the meaning of data for production increases security due to the use of cybersecurity solutions to protect valuable information.

The impact of industry 4.0 can be leveraged through collaboration with universities. The educational programs presented in Chapter 2, carried out in partnership with HEIs and companies, show that synergy is possible.

Recommendations

3 Recommendations

3.1 Recommendations background

The purpose of this chapter is, firstly, to encourage the transformation of enterprises towards Industry 4.0, which is served by various indicators of maturity assessment, presented in Chapter 1. Secondly, we want to encourage enterprises to cooperate extensively with universities, local government units, non-governmental organizations, foundations, etc. The effect of this cooperation should be a joint, sustainable development of the economy towards digital transformation.

4.2 Action plan

Application of Industry 4.0 as a radical change needs planning and supporting actions. The most important aspect is communication within the organization, which will present the aims of the transformation, and the roadmap to obtain them.

Therefore, the emphasis on transferring knowledge within the organization is necessary. It can be obtained by inter-departmental training on a micro and macro scale, and through the openness of communication. The practice may take the form of simulations and roleplay workshops. As a result, the employees should know the goal and strategy of the company.

The employees should be engaged in the transformation through their own ideas, programs, and time for self-development.

The changes proposed by Industry 4.0 are essential. Therefore, they should not be introduced rapidly. A company should initially prepare facilities and tools for retraining workers to be ready for the project and task-oriented work, as well as fast changeover.

4.3 Recommendations

Industry 4.0 employees should know cybersecurity issues and understand the communication processes between the internal IT system, the third-party providers, the government systems, and the client. Cooperation forms and client support are changing. Employees facing new challenges should be able to identify the shortcomings of their competencies and have opportunities for training and mentoring. A dynamically changing work market forces them to be more open to change, ready for further training, and proactive.

New times need new leaders that understand the new environment, can motivate for change, and take risks. Growing access to massive data and its utilization in the production process makes critical and analytical thinking valuable. On the other hand, remote teamwork and an individual approach to the client raise new management problems. A new leader will be a precursor who shares new knowledge, and who identifies and manages talents in newly ensued fields of activity.

However, many of leaders' traits stay the same as we expect today. They should be ready to change their own thinking, perspective, empathetic, open to innovations, courageous, and decision-taking.

The changes will influence a work organization. The structure of new organizations will be flatter. The role of some departments will be reduced or disappear. Work will be focused on dynamically created, project teams.

4.4 Risks and obstacles

The implications of the fourth industrial revolution are unknown. Industry 4.0 brings hopes of ongoing progress, economic growth, and skill upgrading. However, there are also fears such as totalitarian control, alienation, job loss, and insecurity. The transformation gives profits to the citizens but also benefits the governments and global private institutions whose intentions are not always clear.

According to apologists for Industry 4.0, its effects will regard productivity, economic opportunities, and the future of work. However, the critics state that these transformations have so far not achieved any of the promises they raised. They undermine that any technical innovation can improve work conditions, work performance, and work relationships in itself [9].

The authors of the study [20] identified Industry 4.0 risks, opportunities, and critical success factors with regards to the industrial performance of SMEs. Their work demonstrated that the major threats facing the adoption of Industry 4.0 in SMEs include a lack of expertise and a short-term strategy mindset. However, they also noticed that training is the essential factor for success and pointed out the prominent role of managers supported by external experts in their success or failure.

Finally, Industry 4.0 needs a wireless network where sensors, industrial and office devices are connected. Within the infrastructure, real-time demands could take immediate action. However, the complex system architecture raises risk challenges in the field of cybersecurity [21].

4.5 Covid-19

COVID-19 has changed consumer behavior, the labor market, and supply chains. However, the crisis has affected the various branches differently. At the same time, not all changes caused by the epidemic should be considered as dis-benefits.

McKinsey prepared the post-COVID-19 gauge of behavior plasticity [22]. The tool was used to calculate the stickiness score for various sectors. It shows that some sectors, such as e-grocery, will keep their high position after the pandemic. In other sectors, such as Education, the current remote status is not acceptable and has no future after COVID because of the social costs of students' isolation. However, even if remote education were abandoned, remote work and virtual meetings are likely to continue, albeit less intensely [23].

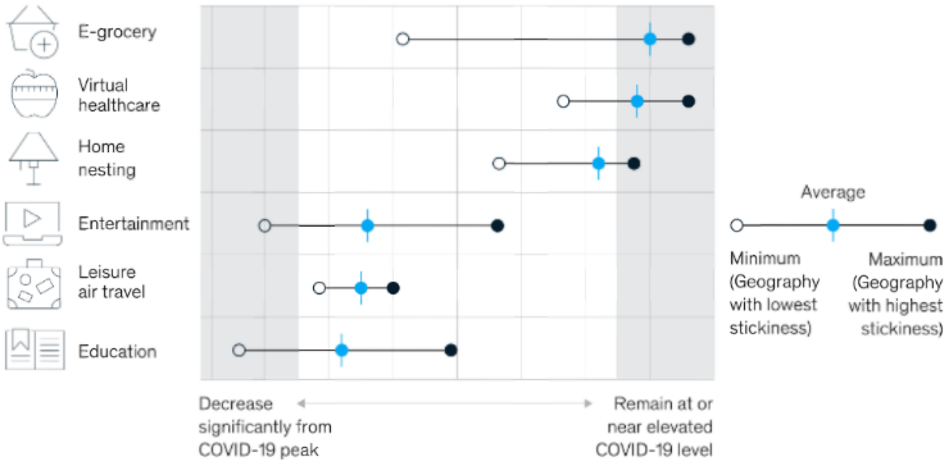

Figure 9 Average and variance of post-COVID-19 stickiness by sector [23]

The authors of the study [24] also tried to answer which professions gained the most during the pandemic and which ones lost.

Apart from identifying the most benefitted sectors (IT, e-commerce, etc.), the authors proposed a set of competencies, which are crucial for the emerging new professions that have arisen in Industry 4.0 and which have been catalyzed by the global pandemic.

According to their research, the epidemic revealed shortcomings in the following competencies of employees:

- inability to adapt to changes,
- innovation and creativity,
- lack of courage to act in a new situation,
- mental strength and resilience,
- self-organization of work,
- proactivity,
- lack of competence to remotely manage,
- fast learning skills,
- IT skills.

It is worth stressing that during our workshops on future challenges in Industry 4.0, the participants predicted most of the mentioned shortages [14]. The after-workshop recommendations are contained in this handbook. Moreover, Industry 4.0 technologies can answer the current issues and help some sectors rebound from COVID-19 [25].

Figure 10 Proposed roadmap for implementation of Industry 4.0 for COVID-19 [25]

The study [26] identified significant challenges acting as operational barriers for the retail sectors and provided Industry 4.0 technologies to deal with the obstacles. Among the challenges faced by the supply chain and retailers during the COVID-19 outbreak are increased lead time, lack of government support, lack of trust, communication issues, lack of security, shortage of workforce, consumers' behavior, lack of balance in supply and demand, poor infrastructure, lack of medical facilities, lack of viability, and lack of access. They also proposed a roadmap for the implementation of Industry 4.04 for COVID-19. The proposed framework can help policymakers to develop an action plan for COVID-19.

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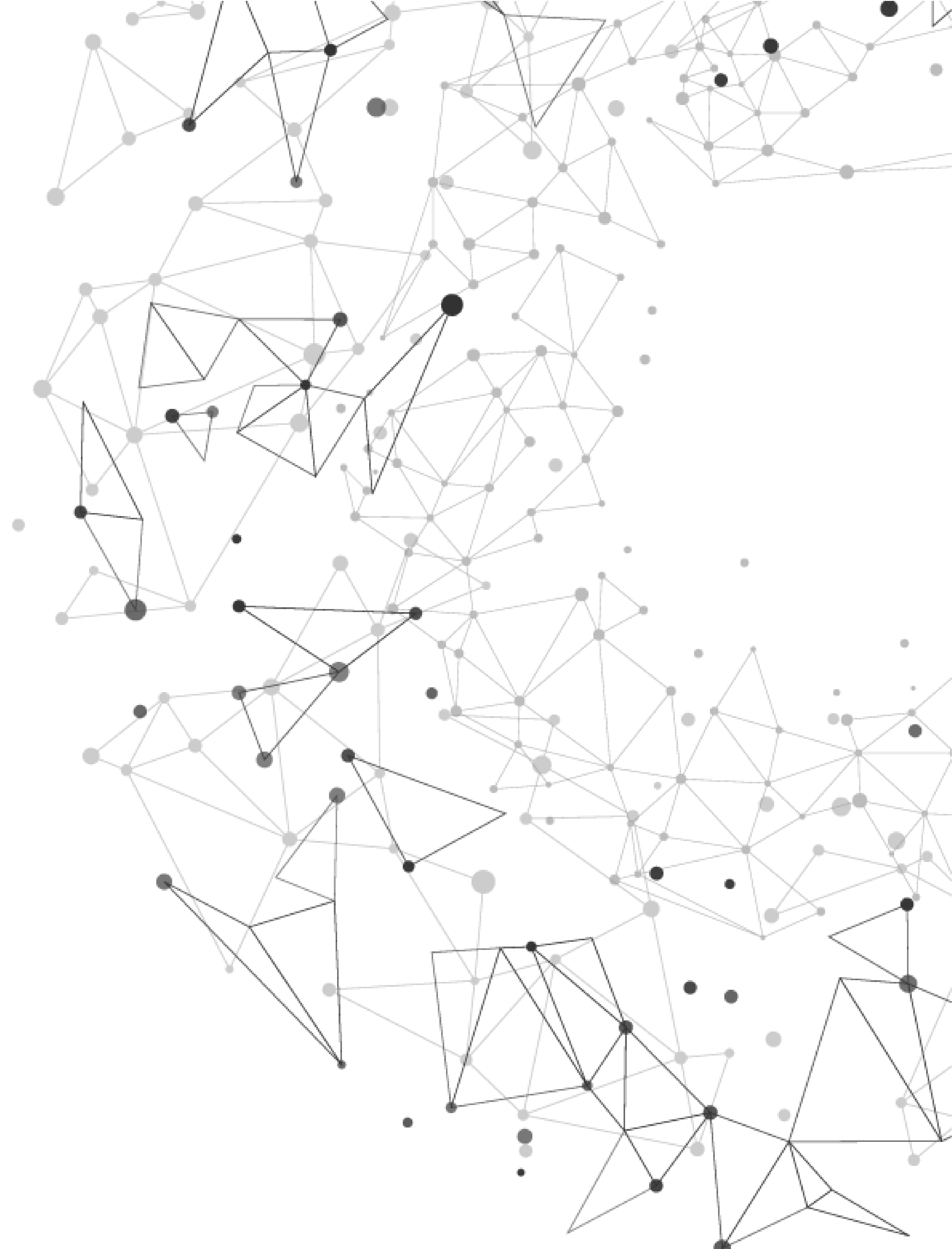

Co-funded by the
Erasmus+ Programme
of the European Union

Universities of the Future is a Knowledge Alliance Project (588409-EPP-1-2017-1-PT-EPPKA2-KA). This project has been funded with the support of the European Commission. This website reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.