UNIVERSITIES OF THE FUTURE

COLLABORATIVE DIGITAL SHIFT TOWARDS A NEW FRAMEWORK FOR INDUSTRY AND EDUCATION

Handbook for Industry

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Introduction

1 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 new three significant challenges. First of them is a lack of skilled workforce that understands new technologies and knows how to make strategic use of information. Second, a lack of knowledge on how to identify future work issues and solutions to address them. Finally, lack of vision and strategy for choosing the proper technology and building system integrating environment.

Higher education institutions can support companies in taking the challenges on, providing a skilled workforce and constant training. Moreover, not only the cooperation is mutually beneficial, as the industry can deliver market insights. It is also providing 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 Industry 4.0 revolution

The handbook presents Industry 4.0 through benefits that can be obtained by an applying company. It describes tools that can be used to estimate a referential Industry 4.0 level and to monitor its development. The handbook describes incentives to cooperate with universities in creating new fields of education, especially when new professions emerge. Besides, it shows what competencies will be needed in the transformation process and how universities can support their development.

Industry 4.0

2 Industry 4.0

2.1 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. Next, the 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 years 2015-2019 that refers 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.

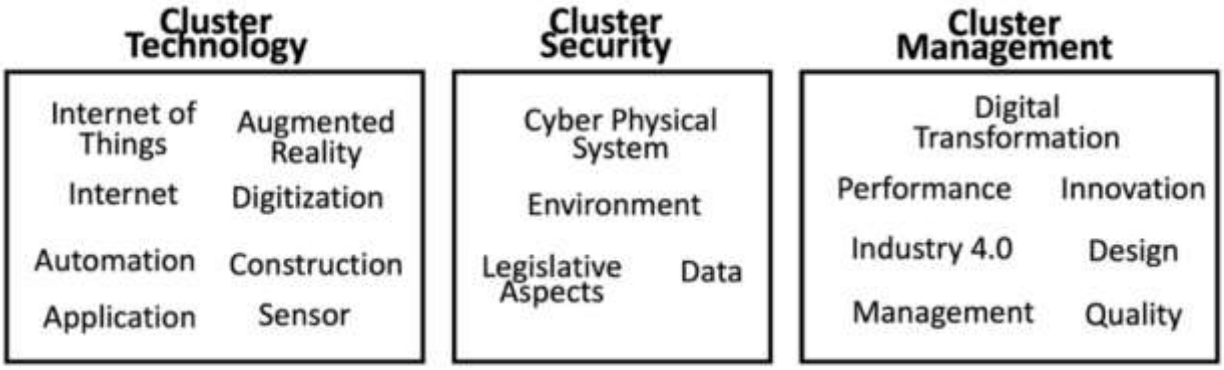

Figure 1 Topics related with Industry 4.0 [2]

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

The complexity of the new revolution was stressed before. Industry 4.0 technologies were found as far-reaching despite their maturity and availability. That embrace political, economic, social, technological, environmental and legal challenges [3]. It was also 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].

2.2 Benefits

Development of Industry 4.0 in a company brings technological benefits. However, introduced changes have more revolutionary than evolutionary character and are not limited to machines. The obtained benefits concern several aspects such as production, management, human resources, support, and cooperation with a social environment.

2.2.1 Improved Efficiency

Improved productivity – less machine downtime and capability to make more products faster.

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

2.2.2 Increased Knowledge Sharing and Collaborative Working

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

With the Industry 4.0 technologies – the digitalization allows 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. DATA Sharing enabled.

2.2.3 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.

2.2.4 Easier Compliance

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

2.2.5 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 problems identification leads to a quicker emergency system response. Digitalization of process and data analysis minimizes issues with product availability and quality improvements. Together, the gains have a direct effect on profitability.

2.2.6 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.

2.2.7 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.

2.2.8 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 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 affects creating of re-skilling and upskilling training opportunities.

Younger workforce, especially engineers, are accustomed to using technologies and expect that their employer will follow the latest trends associated with the digital era. The new approach affects engineering, business and design competences, which companies will have to improve to attract and retain the workforce.

2.2.9 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 of 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.

2.3 Assessment of Industry 4.0 development

2.3.1 Industry 4.0 development in various branches

Capgemini report [8] assesses an Industry 4.0 maturity according to two factors. The first factor - a 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 [8]

Figure 2 shows the digital maturity matrix for selected branches. Trades at the beginning of the journey are Pharmacy and Manufacturing. Well-developed digitalization is in Travel and hospitality when Insurances lead the way in the transformation management. Digital masters are Banking and High Technology companies.

2.3.2 Industry 4.0 Maturity Index

Another measurement method proposed in [9] is the Industrie 4.0 Maturity Index. The authors define capability stages that lead to Industry 4.0. Figure 3 presents the following six phases.

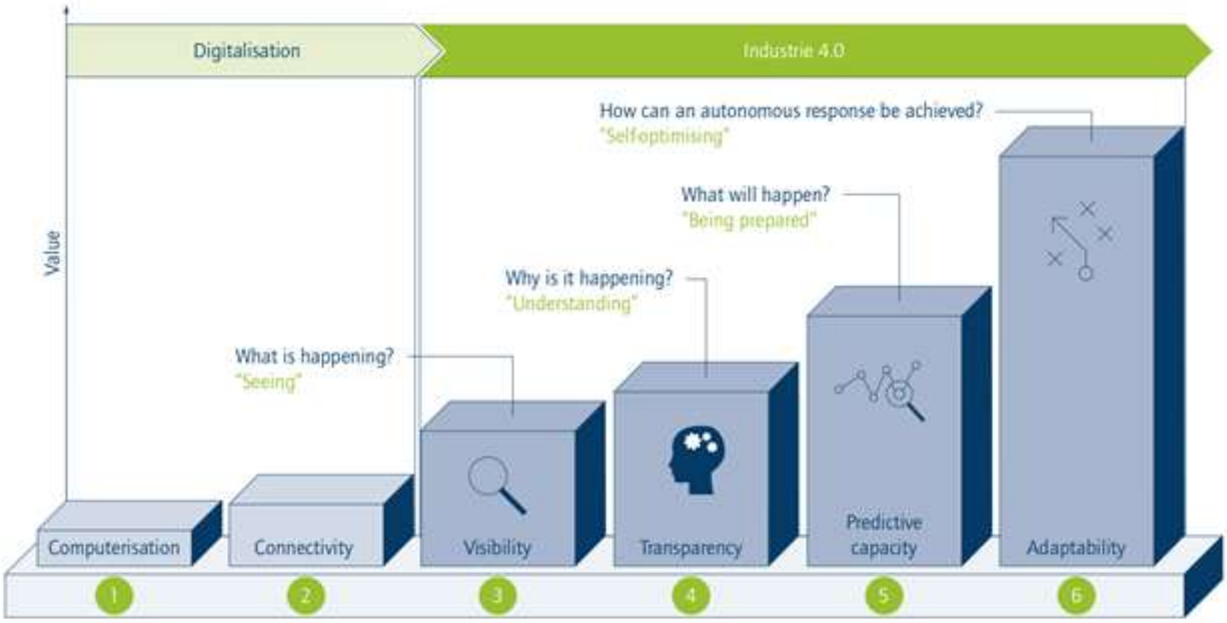

Figure 3 Stages in the Industrie 4.0 development path [9]

The first ones are Computerization & Connectivity. The computerization supports business processes digitally and shared platforms replace isolated applications. Next stages are Visibility & Transparency. Gathering distributed real-time data together, a company increases visibility when information about the processes become available and more exhaustive. A created transparency makes enabled. The following 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 lay-offs to be conservative. The prediction adapts to a changing business environment. Based on past feedback on specific events and their respective outcomes, the systems learn and improve further decision.

2.3.3 Industry 4.0 Digital Compass

For discussion of an application of Industry 4.0 in various business aspects, the McKinsey company created the McKinsey Digital Compass maps Industry 4.0 [10]. The compass - presented in Figure 4 - defines eight main value drivers.

Figure 4 McKinsey Digital Compass [10]

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 but also knowledge work. 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 driver because rework of invalid products leads to extra costs. It can be managed by Advanced process control (ACP) and Statistical process control (ACP). 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/after sales since service costs drive the costs of operation. The after-sales services can be operated through predictive and remote maintenance and visually guided self-service. The next driver, Resource process generates wastes that can be reduced using a 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 allows us to assess how completely an industry 4.0 tools were introduced in the company.

2.3.4 Industry 4.0 Radial chart

A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises was proposed by academic's authors in [11]. The authors summarized several previous models and introduced a new one using nine dimensions: Strategy, Leadership, Customers, Products, Operations, Culture, People, Governance, and Technology. By 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 [11]

Industry and Education 4.0

3 Industry and Education 4.0

3.1 Needs

Impact of Industry 4.0 is significant not only for business but for the whole society. Progressive automation eliminates workers from the market, as they can be possibly replaced by robots, algorithms, or automation. 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. Developing automatic programming may eliminate programmers from the labor market. New employees' traits and skills will be sought and necessary. Therefore, changes must happen both in industry and education process.

The changes in work organization: smaller teams, remote work, and international cooperation forces industry and higher education institutions (HEI) units to rethink priorities in offered professional education. 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.

3.2 Cooperation with HEI

A part of HEI centers is 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.

3.2.1 Individual Academic Programs

As an example of university attitude to collaboration with business, some action took by the Warsaw University of Technology (WUT) are presented. The university, as well as separate faculties, established a board consisted of members of business interested in the education of current students, which are their potential employees. A consultation with the board shows that the alumni have fundamental knowledge and professional competence. However, there is a lack in their soft skills essential in Industry 4.0, such as teamworking, communication, and others.

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

To prevent the education of students poorly adapted to the future labor market, 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 a 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 learn cooperation and communication within the team and with clients. To obtain the aim, the students cooperate with business partners. There are also specialized courses started at selected faculties that focus on specialized students such as IT students.

Specifically one of the courses led by WUT was Forge for Industry 4.0 Leaders. The programme addressed to future candidates for the Masovian Centre for Industry 4.0 Competence. The programme includes activities (workshops, meetings, trainings) aimed at educating and shaping the engineers of the future, Industry 4.0 staff. On a course that applies the Design Thinking (DT) methodology, students learn about tools and technologies related to Industry 4.0 that they will use to solve a problem proposed by the Ministry of Economic Development. The programme was created to make the future leaders better adapted to the changing conditions of business, including industrial activity. The programme was prepared by the Ministry of Economic Development to better prepare future Industry 4.0 personnel to perform tasks related to the preparation of activities for the industrial transformation in Poland [19].

The created center built up a reputation and now is a part of international networks SUGAR and DFGN.

3.2.2 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 academics teachers, form inter-cultural, multidisciplinary teams and work together on exciting design challenges provided by corporate partners. During nine months, the students alongside companies work together 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 [13]. 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.

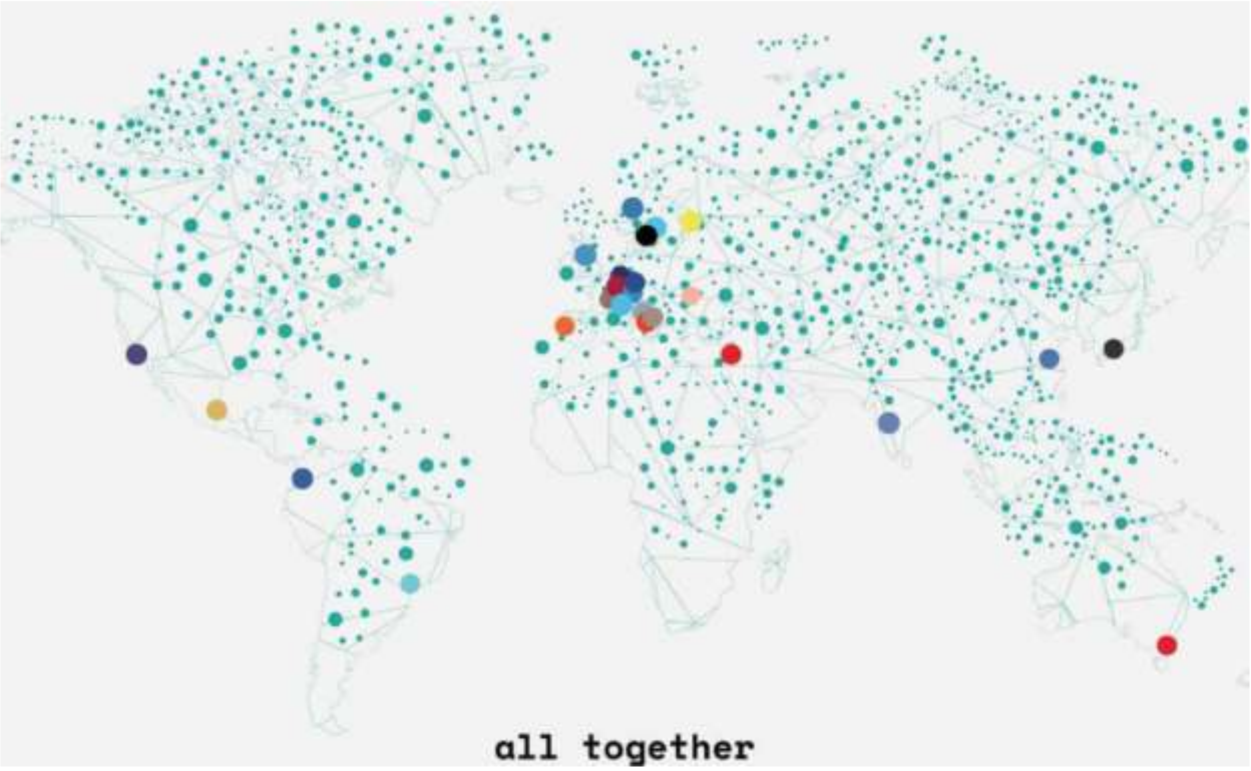

Figure 7 SUGAR Network [12]

3.2.3 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. 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) [15], 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, concepts 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 [14]

3.2.4 National and International Cooperation Programs

In many countries exists national research and development centers that support research units and enterprises in developing their abilities to create and apply solutions based on scientific research results. The centers grant academic groups and business cooperation to establish the economy and to benefit society.

Usually at the center exists a contact point that provides information about the current program offer. The point tasks include supporting clients in defining research and development projects, providing information about specific competition documentation and national ecosystem supporting research and development activities.

Apart from the national centers, there are international programmes. Horizon 2020 [16] is the most significant European Union Research and Innovation programme 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 technologies innovation across a range of sectors. The programme supports public-private partnerships and simplifies granting procedures.

3.3 Industry benefits

Industry 4.0 offers a unique opportunity to redesign SME production processes and to adopt new business models [17]. Security increases due to the use of cyber security solutions. In the information age, any information brings measurable, monetary profit, which is why BigData solutions are indisputably appropriate. Going further, continuous information about the state of devices, systems implemented by sensors is also very valuable and brings measurable profits. Simulation and optimization of processes using modern algorithms also brings financial benefits. All this can be done better in cooperation with universities. The educational programs presented in Chapter 3, carried out in cooperation with HEI and companies, show that synergy is possible.

Recommendations

4 Recommendations

4.1 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 2. 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 that will present the aims of the transformation and 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 openness of communication. The practice may take a form of simulations and role-play workshops. In the result, the employees should know the goal and strategy of the company.

The employees should be engaged in the transformation by employee ideas programs and time for self-development.

Before the change, the company should prepare facilities and tools for retraining, be ready for a project and task work and fast changeover.

4.3 Recommendations

Employees in Industry 4.0 environment should know - because of new risk and threats - cybersecurity issues and the communication process between the internal IT system, the third-party and government systems and the client.

Growing access to massive data and its utilization in the production process makes critical and analytical thinking valuable. A cooperation form and client support are changing. Remote teamwork and individual approach to the client raise new management problems. Employees facing new challenges should be able to identify the shortcomings of their competences and have opportunities for training and mentoring. Dynamically changing work market forces them to be more opened to change, ready for further training, and proactive.

New times need new leaders that understand the new environment, can motivate for change and take its risk. A new leader will be a precursor who shares new knowledge, can identify and manage talents in newly ensued fields of activity. However, many of his or her traits stay the same as we expect today. He or she should be ready to change thinking, prospective, empathic, open to innovations, courageous, and decision-making.

The changes will influence a work organization. The structure of new organization will be flatter. A role of some departments will be reduced and finally, the departments may disappear. Work will be focused on task-oriented 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 assessment as 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 [8].

The authors of the study [17] 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 a prominent role of managers supported by external experts in 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 rises risk emerges in the field of cybersecurity [18].

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