D 4.1
Identification of emerging skills and job requirements (V.0.9)

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1 PU: Public, CO: Confidential, only for members of the consortium (including the Commission Services)
2 RE: Report, OT: Other; ORDP: Open Research Data Pilot

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Abbreviations and acronyms

TERMS, ABBREVIATIONS AND ACRONYMS	
CA	Consortium agreement
CO	Coordinator
DoA	Description of Action
DPO	Data Protection Officer
EB	Executive Board
EC	European Commission
GA	Grant Agreement / General Assembly
ORDP	Open Research Data Pilot
QM	Quality Manager
QMP	Quality Management Plan
SyGMa	System for Grant Management
WP	Work package
WPL	Work Package Leader

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Executive Summary

The introduction of digital platforms and the use of modern manufacturing technology creates a need for new skills within a company's workforce, which have historically not been appropriate. Aspects like lifelong learning and new paradigms in education are becoming more and more relevant. WP4 deals with the identification of the related training and courses available to industrial workers/managers that fit the skills needed to advance the paths of the ConnectedFactories, identify delivery mechanisms, list appropriate online offerings, and review academic and technical curricula to recognize gaps and guide them. This Deliverable (D4.1) especially focuses on the Identification of emerging skills and job requirements [Months: 1-36] and is presenting the following aspects:

- **An overview of Digital Transformation Emerging Skills Requirements**: Recent studies have been conducted in the field of skills and job profiles in industry 4.0; Market developments, Technological trends related to Big Data, Autonomous Robots, Digital Twin, Industrial Internet of Things, Cybersecurity, and Cyber-Physical Systems, etc. and Overview of relevant initiatives have examined.
- **Skills for the manufacturing of the future**: Based on studies conducted in World Economic Forum and World Manufacturing Forum, the skills required for industry 4.0; Mechanisms for implementing these skills, how to move from industry 4.0 to industry 5.0; How to communicate artificial intelligence in industry and manufacturing and the skills required to communicate with artificial intelligence are discussed.
- **Future Skills Matching with CF1 Pathways (Introducing 6Ps People dimension)**: This model, which examines six different aspects of pilots (Product-Process-Platform-People-Partnership-Performance), that generally adopted by the University of Politecnico di Milano and has been implemented and analyzed in previous European projects such as BOOST4.0, MIDIH, and CAPRI.
- **Professions and Skills Analysis for CF2 Pathways**: Five job profiles presented related to Data Science Management and have been the subject of a detailed survey proposed to pilots in order to highlight pilots' current status, requirements for the future, and approaches to be adopted. This Surveys are also generally adopted by the University of Politecnico di Milano and have been implemented and analyzed in previous European projects such as BOOST4.0.
- **Roles and Professions for Circular Economy Pathways**: This chapter reflects on the needs for new professions and skills related to digitally-enabled development of the circular (and sustainable) manufacturing industry. After explaining the variety of roles and Professions and their skills by VTT, these roles have been examined in industrial cases (KYKLOS and digiPRIME).
- **Roles and Professions in the CyberSecurity pathway**: LSEC provides an answer to the question: "Which skills do you think are required for a CyberSecure Connected Factory?" and mentions due to the increasing complexity of CyberSecurity, additional roles and Professions will need to be organized, likely duplicating or splitting the three identified roles and therefore adding additional layers of complexity in the organization and adding skills related to the specific functions, and subsequent skills required (i) Cybersecurity Management, (ii) Operations Management, (iii) Field Engineer – Operator

Keywords: Industry 4.0, Digital Transformation, Emerging Skills Requirements, 6Ps People dimension, Data Science Management, Circular Economy, CyberSecurity.

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1 Introduction

Industry 4.0 is introducing radical changes and challenges in manufacturing companies. While Industry 3.0 focused on the automation of specific business processes, Industry 4.0 focused on enterprises' digital transformation.

The main challenges are related to the introduction in industrial practices the use of digital tools that include advanced collaborative robots, cloud computing, big data and analytics, 3D printing, Internet of Things, mobile, augmented, and virtual reality.

Engineers and blue-collar workers will need new lifelong learning schemes to be assisted in keeping up with the pace of change. The rapid advancements in manufacturing technology and Information and Communication Technologies (ICT) have set on manufacturing education an intense requirement for a continuous update of the knowledge content and delivery schemes. The comprehension of the technical essence and the business potential of new knowledge /technology is essential for its smooth adaptation and integration into the industrial working practice[3].

Skills and job profiles play an important role in companies' efforts to embrace new technologies and practices. Evolution emerges simultaneously in all possible directions. Existing skills should be integrated into job profiles. New skills should be developed to properly address the new digitalization trends. New profiles should be described to better match the needs of the companies. This deliverable identifies emerging, new skills and job requirements that are in accordance with the pathways previously developed in Connected Factories1, as well as with the pathways that are developed in Connected Factories 2.

This deliverable identifies emerging, new skills and job requirements that are in accordance with the pathways previously developed in Connected Factories1, as well as with the pathways that are developed in Connected Factories 2.

The document is structured as follows:

In chapter 2, an overview of market developments and technological trends is being presented. State of the art material as well as recent reports from various stakeholders are used in order to give an overview of the need for digital skills in manufacturing.

In chapter 3, a matching of future skills needed to support the digital pathways defined in Connected Factories I are presented. Chapters 4 to 6 analyse the digital skills needed to support the newly defined pathways for “Data Sharing”, “Circular Economy” and “Cyber Security”.

3 George Chryssolouris, Dimitris Mavrikios, Dimitris Mourtzis, Manufacturing Systems: Skills & Competencies for the Future, Procedia CIRP, Volume 7, 2013, Pages 17-24, ISSN 2212-8271, https://doi.org/10.1016/j.procir.2013.05.004.

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2 An overview of Digital Transformation Emerging Skills Requirements

2.1 Introduction

The Industry 4.0 concept has emerged from an initiative supported by academics and the industry along with the support of the German Government. The initiative aims at strengthening the competitiveness of the manufacturing industry through the convergence between production processes and Information and Communication Technologies (ICT) [4] Industry 4.0 utilizes technologies such as the as the Internet of Things (IoT) and services (IoS), Cyber Physical Systems (CPS), cybersecurity, smart robotics, augmented and virtual reality technologies, to improve the productivity of the industrial manufacturing systems. As a result of the increased use of digital technologies, the boundary between the real and the digital world is increasingly obscuring, leading to what is known as cyber-physical production systems. Despite the considerable attention paid to the topic of Industry 4.0, research on the changes in the jobs and skills required by Industry 4.0 are still developing. Learning and training are fundamental key factors for achieving the Industry 4.0 objectives as they will significantly transform the job and skills profiles of the blue and white-collar workers.

We are in the age of the Fourth Industrial Revolution. New skills requirements are changing rapidly, and enterprises, especially SMEs, struggle to find the talent they need. On the other hand, due to the digitalization of many processes and the high speed of progress in this field it has created new needs in **society** as well as in the **business environment**.

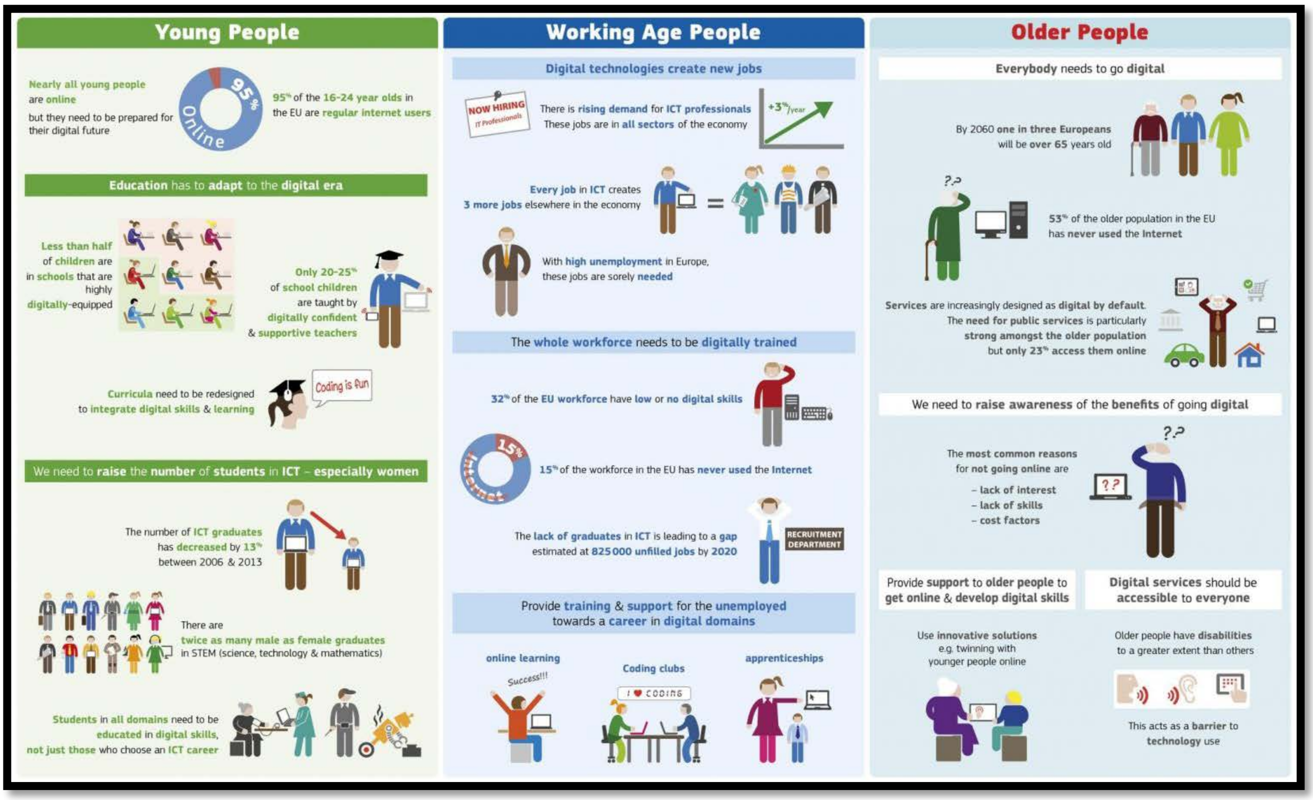

Figure 1 A digital Europe need digital skills

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4 H. Kagermann, J. Helbig, A. Hellinger, and W. Wahlster, Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group. Forschungsunion, 2013.

As Figure 1 depicts, according to previous research in " Shaping Europe's digital future"[5], in case of need to digital skills in **society**, people divided to 3 categories:

- **Young people:** In this category almost 95%, who are between 16-24 years old are internet users so in this case education must adapt to the digital era. In addition, society need to raise the number of students in ICT because the number of ICT graduates has decreased 13% between 2016 to 2013.

- **Working age people:** In this category, this issue can be mentioned that digital technologies create new jobs and opportunities, and it should be noted that each job in ICT creates 3 more jobs elsewhere in the economy. In addition, here also the whole workforce needs to be digitally trained.

- **Older people:** In this category, society needs to raise awareness of the benefits of going digital, for instance by providing supports to older people to get online and develop digital skills.

2.2 Market developments

With the advent of the industry 4.0 revolution, there has been a significant transformation in the manufacturing sector in the form of digitization and automation. Industry 4.0 has been aiding the transition of industries from having legacy systems to smart components and smart machines, facilitating digital factories, and later, to an ecosystem of connected plants and enterprises.

The *global Smart Manufacturing market* was valued at USD 183.62 billion in 2019 and is expected to register a CAGR of 8.4% to reach USD 293.92 billion over the forecast period (2020-2025) [6]. Anticipating the increased adoption of IoT and digital transformation across industries, the European Commission estimated that IoT's value in Europe itself is expected to exceed EUR 1 trillion in 2020.

The global B*ig Data market* size to grow from USD 138.9 billion in 2020 to USD 229.4 billion by 2025, at a Compound Annual Growth Rate (CAGR) of 10.6% during the forecast period[7]. The major growth factors of the big data market include the increasing awareness of the Internet of Things (IoT) devices among organizations, increasing availability of data across the organization to gain deeper insights to remain competitive, and increasing government investments in various regions for enhancing digital technologies.

MarketsandMarkets forecasts the *Industrial Robotics market* size (including the prices of peripherals, software, and system engineering) to grow from USD 48.7 billion in 2019 to USD 75.6 billion by 2024, at a Compound Annual Growth Rate (CAGR) of 9.2% during the forecast period[8]. Technological advancements and decreasing costs are making industrial robots more affordable to SMEs and are enabling seamless integration and programming. The shortage of labor and increasing manufacturing requirements is driving the need and acceptance for automation.

The global *Additive Manufacturing market* is expected to reach USD 26.68 billion by 2027[9], growing at a high rate of 14.4%, according to a new report by Reports and Data. Increasing government support to enhance additive manufacturing technology across various regions is a key factor influencing market demand.

5 https://ec.europa.eu/digital-single-market/en/news/digital-europe-needs-digital-skills
6 Mordor Intelligence, 2020, SMART MANUFACTURING MARKET - GROWTH, TRENDS, AND FORECASTS (2020 - 2025)
7 MarketandMarkets, 2020, Big Data Market - Global Forecast to 2025
8 MarketandMarkets, 2019, Industrial Robotics Market by Type - Global Forecast to 2024
9 Reports and Data, 2020, Additive Manufacturing Market

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According to the studies conducted by Mc Kinsey & company – " The Future of Work in Europe- 2020"[10] Based on questions about people's expectations regarding to see "skill gaps as market and technology trends alter organizations' talent needs" the following results (Figure 2) were obtained.

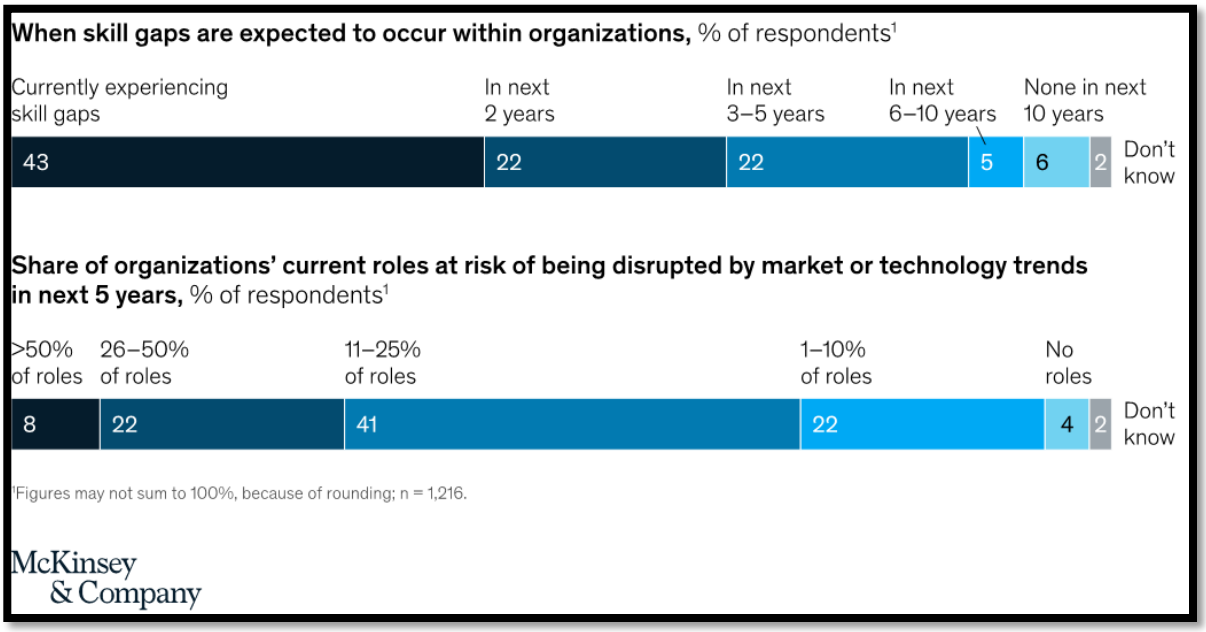

Figure 2 Market and Technology trends

Based on these results, it can be concluded that, 43% of respondents believe which currently they are experiencing skill gaps in their organizations, while 22% believe that they will face in next 2 years with this gap and the same percentage is also believe they will face in next 3-5 years and few percentages voted to more than 6 years. Analyzing these responses shows that the technology and market is changing and developing very fast which many organizations are already facing these changes and many will touch it in the very near future in their business.

In addition, according to second analysis about " share of organizations' current roles at risk of being disrupted by market or technology trends in next 5 years" and based on respondents' expectation, it can be concluded that: 41% believe something between 11 to 25% of roles will disrupted in next 5 years and 22% believe this percentage is between 1 to 10 % and same percentage of participants believe 26 to 50% of roles will disappeared or replace by new roles in next 5 years. The analysis of these answers shows that the market and technology will change and grow a lot in the next 5 years, so that many of the existing roles will be affected by the new trend and as a result; will be removed, modified, or replaced.

2.3 Technological trends

This chapter presents an overview of the latest technological trends in the area of manufacturing. The objective is not to provide an extensive review of the advanced, new technologies that are being adopted in manufacturing but to present the main technologies that have an impact on skills and job profiles. There are several technological trends that are considered under the umbrella of Industry 4.0. Although there are several schemes on the key technologies that are employed to support the digital transformation (see for an example), there is not a widely adopted classification scheme of relevant technologies or a widely adopted list of technologies that have a significant contribution to the transformation of "traditional" industries to

10 https://www.mckinsey.com/featured-insights/future-of-work/the-future-of-work-in-europe#

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"factories of the future". In this document we have adopted the "nine-pillars" scheme[11,12] as it probably includes the most acknowledgeable ones.

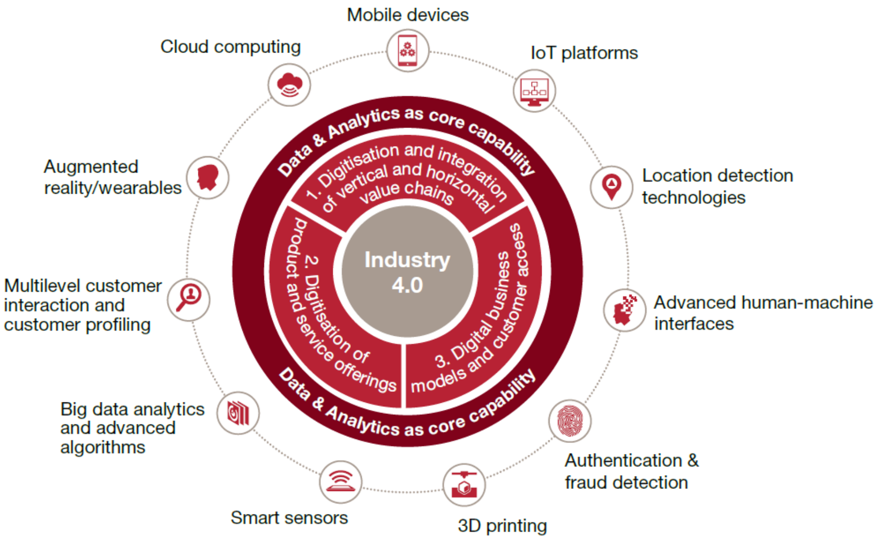

Figure 3: Industry 4.0 framework and contributing digital technologies (source PwC[13])

The Report from World Economic Forum also indicates the technologies and technological trends are expected to have a significant impact in period 2020-2025 as shown in Figure 4 below.

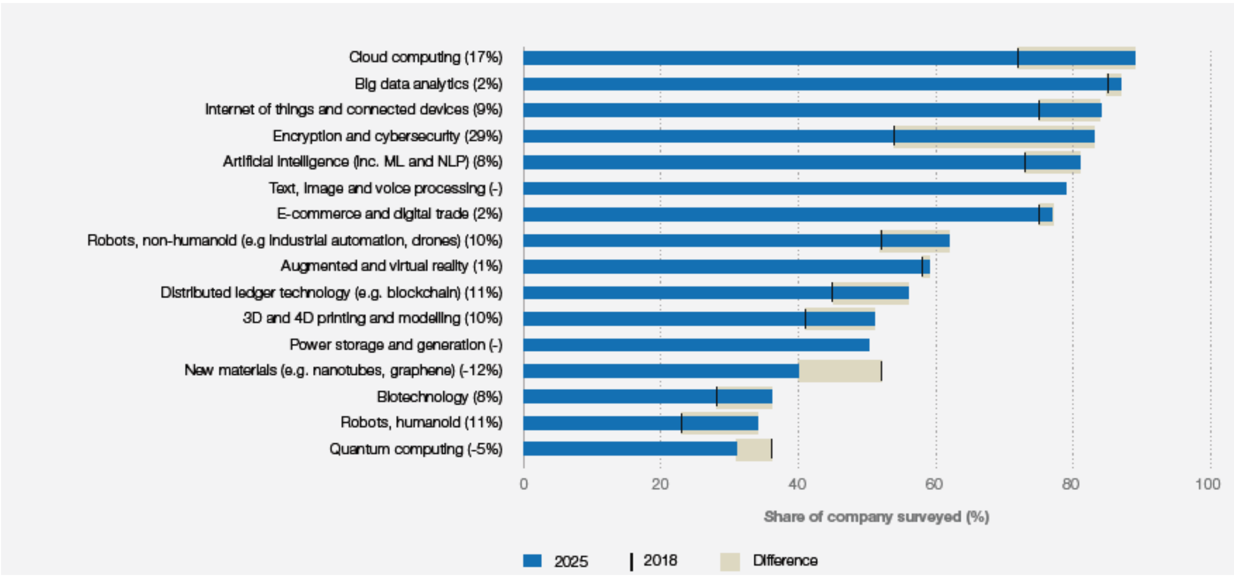

Figure 4: Technologies likely to be adopted by 2025-Future of Jobs Survey 2020, World Economic Forum

11 Gizem Erboz, How to Define Industry 4.0: The Main Pillars Of Industry 4.0, 7th International Conference on Management (ICoM), 2017
12 Saurabh Vaidya, Prashant Ambad, Santosh Bhosle, Industry 4.0 – A Glimpse, 2nd International Conference on Materials Manufacturing and Design Engineering, Procedia Manufacturing 20 (2018) 233–238,
13 PwC, Industry 4.0: Building the digital enterprise, 2016

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2.3.1 Big Data and Analytics

The smart factory's big data mainly include real-time sensor data, machine log, and manufacturing process data, which have large volume, multiple sources, and spare value. In the context of intelligent manufacturing, the applications of big data develop rapidly in industrial supply chain analysis and optimization, product quality control, and active maintenance[14]. New technologies, such as Cloud computing, enable the analysis of Big Data through the Internet providing ubiquitous access to information. A key challenge is the handling of Big Data generated from the diverse sources of a manufacturing system using Big Data analytic techniques to support decision making. The management and visualization of data from heterogeneous data sources[15].

2.3.2 Autonomous Robots

Autonomous robots perform autonomous production more precisely and can work together with humans. They have the ability to complete assigned tasks accurately, flexible, versatile, and in a collaborative fashion. The robotic systems will have to decide on the reaction steps to be followed through perception and evaluation of its state as well as its capabilities. The autonomous resources will settle on the task to be undertaken and then automatically navigate to the specific area, be plugged into the system, and have the task realized[16]. These days, as human-robot collaboration becomes more efficient and easier to use, a variety of manufacturing industries aspire to introduce it in their production lines. Wearable devices, an advanced user interface including audio and haptic commands accompanied by augmented reality technology, are used to support the operator and provide awareness by visualizing information related to production and safety aspects[17].

2.3.3 Simulation and Digital Twin

Manufacturing systems simulation has proven to be a powerful tool for designing and evaluating a manufacturing system due to its low cost, quick analysis, low risk, and meaningful insight that it may provide, improving the understanding of each component's influence. The simulation comprises an indispensable set of IT tools and methods for the successful implementation of digital manufacturing. It allows experimentation and validation of the product, process, and system design and configuration [18]. Simulation can be driven by real-time data collected from physical assets and products. A Digital Twin model comprises of three main parts: a) the real world, b) the virtual world model, and c) the connections of information associating the virtual with the real world, with the digital twin serving as a digital controller of the real-world manufacturing system[19]. DT model may include simulation models that are used to control applications on the shop-floor[20].

2.3.4 Horizontal and Vertical System Integration and interoperability

Industry 4.0 has amplified the importance of horizontal and vertical integration, making them the very backbone on which the Smart Factory and Smart Value-Added networks are built. Vertical integration connects machine and production units to higher levels of the ISA-95 model. Devices, control units, MES, and ERP systems communicate performance and status data and they are capable to respond to dynamic

14 B. Chen, J. Wan, L. Shu, P. Li, M. Mukherjee and B. Yin, "Smart Factory of Industry 4.0: Key Technologies, Application Case, and Challenges," in IEEE Access, vol. 6, pp. 6505-6519, 2018, doi: 10.1109/ACCESS.2017.2783682.

15 D. Mourtzis, E. Vlachou, N. Milas, "Industrial Big Data as a result of IoT adoption in Manufacturing", CIRPe2016 , Procedia CIRP, 5th CIRP Global Web Conference-Research and Innovation for Future Production, Volume 55, pp. 290-295 (2016)

16 G. Michalos, S. Makris, G. Chryssolouris, "The new assembly system paradigm", International Journal of Computer Integrated Manufacturing, Available Online (2014)

17 Papanastasiou, S., Kousi, N., Karagiannis, P. et al. Towards seamless human robot collaboration: integrating multimodal interaction. Int J Adv Manuf Technol 105, 3881–3897 (2019). https://doi.org/10.1007/s00170-019-03790-3

18 Dimitris Mourtzis (2019): Simulation in the design and operation of manufacturing systems: state of the art and new trends, International Journal of Production Research, DOI: 10.1080/00207543.2019.1636321

19 Grieves, M. (2014). Digital Twin: Manufacturing Excellence through Virtual Factory Replication 1–7

20 Kosmas Alexopoulos, Nikolaos Nikolakis & George Chryssolouris (2020): Digital twin-driven supervised machine learning for the development of artificial intelligence applications in manufacturing, International Journal of Computer Integrated Manufacturing, DOI:10.1080/0951192X.2020.1747642

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production requirements autonomously. Horizontal integration is applied across multiple production facilities as well as the entire supply chain.

2.3.5 Industrial Internet of Things (IIoT)

The main task of IoT is to collect data from physical objects and connect them to the Internet. By collecting data, computers or higher-level devices (e.g. gateways) make the decision about industrial processes. The huge amount of data that are generated by IoT require sophisticated processing capabilities. Methodologies such as context-aware computing will facilitate the decision making on which data will be processed and in which layer in some ICT infrastructure[21]. Moreover, middleware and cloud platforms have been developed to integrate the IoT data and host the generated higher-level information[22].

2.3.6 Cybersecurity and Cyber-Physical Systems (CPS)

One of the most significant advances in the development of computer science, information and communication technologies is represented by the cyber-physical systems (CPS). They are systems of collaborating computational entities that are in intensive connection with the surrounding physical world and its on-going processes, providing and using, at the same time, data-accessing and data-processing services available on the Internet. Cyber-physical production systems (CPPS), relying on the latest, and the foreseeable further developments of computer science, information and communication technologies on one hand[23]. CPS concept in manufacturing has several applications such as in control and maintenance[24, 25] and human-robot collaboration[26].

Digital manufacturing aims to create highly customizable products with higher quality and lower costs by integrating the Industrial Internet of Things, big data analytics, cloud computing, and advanced robots into manufacturing plants. As manufacturing machines are increasingly retrofitted with sensors as well as connected via wireless networks or wired Ethernet, digital manufacturing systems are becoming more accessible than ever. While advancement in sensing, artificial intelligence, and wireless technologies enables a paradigm shift in manufacturing, cyber-attacks pose significant threats to the manufacturing sector[27]. Therefore, preventable solutions and cybersecurity systems are necessary against the negative effects of terror incidents.

2.3.7 The Cloud

Cloud computing is changing the way industries and enterprises do their businesses in that dynamically scalable and virtualized resources are provided as a service over the Internet. This model creates a brand new opportunity for enterprises. There are three models of cloud computing; Software as a Service (SaaS) where the access depends on the customer purchase such as ERP, Platform as a Service (PaaS) where customers are allowed to access their applications on the cloud such as software developers and Infrastructure as a Service (IaaS) offers the basic activities such as storing capabilities. In terms of cloud

21 K. Alexopoulos, S. Makris, V. Xanthakis, K. Sipsas, G. Chryssolouris, "A concept for context aware computing in manufacturing: the white goods case", International Journal of Computer Integrated Manufacturing, Available Online (2016)

22 K. Alexopoulos, K. Sipsas, E. Xanthakis, S. Makris & D. Mourtzis (2018): An industrial Internet of things based platform for context aware information services in manufacturing, International Journal of Computer Integrated Manufacturing, DOI: 10.1080/0951192X.2018.1500716

23 Monostori, B. Kádár, T. Bauernhansl, S. Kondoh, S. Kumara, G. Reinhart, O. Sauer, G. Schuh, W. Sihn, K. Ueda, Cyber-physical systems in manufacturing, CIRP Annals, Volume 65, Issue 2, 2016, Pages 621-641, ISSN 0007-8506, https://doi.org/10.1016/j.cirp.2016.06.005.

24 D. Mourtzis, K. Vlachou, "A cloud-based cyber-physical system for adaptive shop-floor scheduling and condition-based maintenance", Journal of Manufacturing Systems, Vol. 47, pp. 179-198 , (2018)

25 N. Nikolakis, R. Senington, K. Sipsas, A. Syberfeldt, S. Makris, "On a containerized approach for the dynamic planning and control of a cyber-physical production system", Robotics and Computer Integrated Manufacturing, Volume 64, (2020)

26 N. Nikolakis, V. Maratos, S. Makris,"A cyber physical system (CPS) approach for safe human-robot collaboration in a shared workplace", Robotics and Computer-Integrated Manufacturing, Volume 56, pg. 233-243, (2019)

27 Dazhong Wu, Anqi Ren, Wenhui Zhang, Feifei Fan, Peng Liu, Xinwen Fu, Janis Terpenny, Cybersecurity for digital manufacturing, Journal of Manufacturing Systems, Volume 48, Part C, 2018, Pages 3-12, ISSN 0278-6125, https://doi.org/10.1016/j.jmsy.2018.03.006.

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computing adoption in the manufacturing sector, the key areas are IT and new business models that cloud computing can readily support, such as pay-as-you-go, the convenience of scaling up and down per demand, and flexibility in deploying and customizing solutions.[28]

2.3.8 Additive Manufacturing

Additive Manufacturing (AM) is a technology rapidly expanding in several industrial sectors. It provides design freedom and environmental/ecological advantages. It transforms design files essentially to fully functional products. AM can deliver parts of very intricate and complex geometries with a minimum need for post-processing, built from tailored materials with near-zero material waste, while being applicable to a variety of materials, including plastics and metals. Therefore, AM is a tool that offers increased "design freedom" and enables designers and engineers to create unique products that can be manufactured at low volumes in an economical way[29].

2.3.9 Augmented Reality

The last few years, technology has arisen in manufacturing that supports the vivid depiction of information, using animations, 3D geometries, and text: augmented reality (AR). AR allows the visualization of information in the field of view of the operator in a way that is highly perceivable and does not cut him off of his environment. Recently, more and more applications of augmented reality have become implemented in manufacturing, beginning with customer-oriented applications to applications to support training in production[30,31]. There are several uses of AR in manufacturing, such as AR for human-robot collaboration[32], maintenance[33] and product design[34].

Apart from the technological enablers a central component of Industry 4.0 is its human-centricity, described as development towards the Operator 4.0 concept[35]. Operator 4.0 refers to smart and skilled operators of the future, who will be assisted by automated systems providing a sustainable relief of physical and mental stress and allowing the operators to utilise and develop their creative, innovative and improvisational skills, without compromising production objectives. Operator 4.0 typology and argued that one operator could incorporate one or several of the proposed types: the Super-strength Operator (e.g., using Exoskeletons), the Augmented Operator (e.g., using augmented reality tools), the Virtual Operator (e.g., using a virtual factory), the Healthy Operator (e.g., using wearable devices to track well-being), the Smarter Operator (e.g., using agent or artificial intelligence for planning activities), the Collaborative Operator (e.g., interacting with CoBots), the Social Operator (e.g., sharing knowledge using a social network) and the Analytical Operator (e.g., using Big Data analytics). In AceFactories white paper[36], the Operator4.0 typology has been adapted () and the links to several technologies that each type of operator 4.0 will be using are discussed.

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28 Xun Xu, From cloud computing to cloud manufacturing, Robotics and Computer-Integrated Manufacturing, Volume 28, Issue 1, 2012, Pages 75-86, ISSN 0736-5845, https://doi.org/10.1016/j.rcim.2011.07.002.

29 H. Bikas, P. Stavropoulos, G. Chryssolouris, "Additive manufacturing methods and modelling approaches: a critical review", The International Journal of Advanced Manufacturing Technology, Volume 83, Issue 1, pp. 389-405 (2016)

30 Nee AY, Ong SK, Chryssolouris G, Mourtzis D (2012) Augmented reality applications in design and manufacturing. CIRP Ann Manuf Technol 61(2):657–679

31 D. Mourtzis, V. Zogopoulos, F. Xanthi, "Augmented reality application to support the assembly of highly customized products and to adapt to production re-scheduling", International Journal of Advanced Manufacturing Technology, pg. 1-12, (2019)

32 S. Makris, P. Karagiannis, S. Koukas, A. S. Matthaiakis, "Augmented reality system for operator support in human–robot collaborative assembly", CIRP Annals - Manufacturing Technology, Volume 65, Issue 1, pp. 61-64 , (2016)

33 D. Mourtzis, E. Vlachou, V. Zogopoulos, "Cloud-based Augmented Reality Remote Maintenance through shop-floor Monitoring: A PPS approach", ASME Journal of Manufacturing Science and Engineering, 139(6) , (2017)

34 L. Rentzos, C. Vourtsis, D. Mavrikios, G. Chryssolouris, "Using VR for Complex Product Design", Virtual, Augmented and Mixed Reality. Applications of Virtual and Augmented Reality, Lecture Notes in Computer Science, Volume 8526, pp.455-464 (2014)

35 Romero, D., Bernus, P., Noran, O., Stahre, J., & Fast-Berglund, Å. The operator 4.0: human cyber-physical systems & adaptive automation towards human-automation symbiosis work systems. In IFIP International Conference on Advances in Production Management Systems (pp. 677-686). Springer, Cham.

36 Ace factories, White paper on Human-centred factories from theory to industrial practice. Lessons learned and recommendations, 2019.

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Figure 5: ACE Operator 4.0 Topology (AceFactories white paper; modified from Romero et al ,2016).

2.4 Labour market trends and needs for skills

In the industry 4.0 all skills are required. This is fundamental because all the previously disconnected technologies and applications have come into convergence. However, the body of the existing workforce will need to change to match the skills required to support the success of industry 4.0. Further, the development of novel technologies such as smart sensors, intelligent assistants, robots, and automation will continue to demand change in the types of skills as well as the labour landscape[37]. Global labor markets are undergoing major transformations, with changes to business needs and workforce profiles picking up an even ,more incredible pace in recent years. The human-centered paradigm shift will only be successful if work processes are reshaped and new training approaches are introduced to support the continuous development of skills taking into account personal capabilities, skills and situational preferences of individual operators[36].

In Figure 6 below the links between labor market needs to skills and competencies development down to qualification acquisition is depicted. The company, market needs require for (new) job profiles that have one or more skills which can be achieved by following specific learning and training courses.

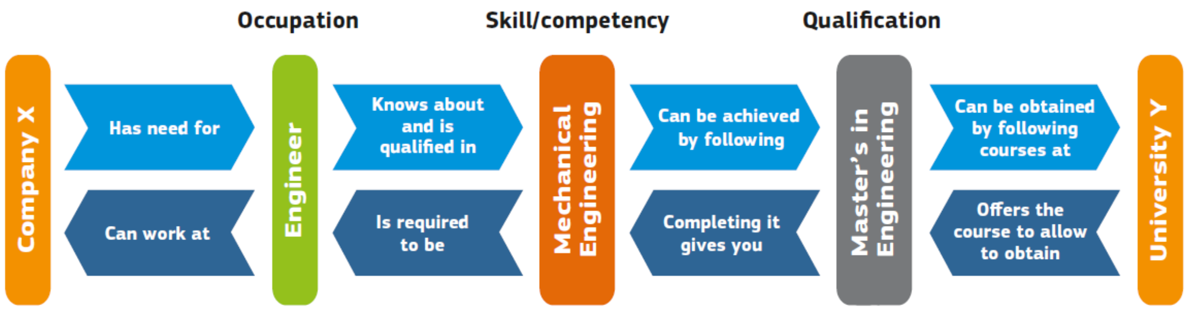

Figure 6: The skills development thread (Source: European Skills, Competences, Qualifications, and Occupations – ESCO)

37 Ocident Bongomin , Gilbert Gilibrays Ocen, Eric Oyondi Nganyi, Alex Musinguzi,and Timothy Omara Exponential Disruptive Technologies and the Required Skills of Industry 4.0, 2020, https://doi.org/10.1155/2020/4280156

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The Future of Jobs Report 2020[38] from World Economic Forum (WEF) maps the jobs and skills of the future. For 2020 the report suggests that "*while technology-driven job creation is still expected to outpace job destruction over the next five years, the economic contraction is reducing the rate of growth in the jobs of tomorrow*". WEF reports estimate the needs in terms of reskilling needed according to the expected needs of the labour market. In Figure 7 below the infographics of the WEF report is presented that mentions that 73,2% of the employees will require a considerable amount of training (i.e., more than one month). Taking into account EU statistical data on employment in manufacturing (see Figure 8) estimation of the effort that needs to be invested for reskilling people in manufacturing can be drawn (see Table 1).

Figure 7: Reskilling needs in Advanced Manufacturing according to WEF 2020 report[38]

Key indicator, Manufacturing (NACE Section C), EU-27, 2017

	Value
Main indicators	
Number of enterprises (number)	1 964 946
Number of persons employed (number)	28 531 905
Turnover (EUR million)	7 230 000
Purchases of goods and services (EUR million)	5 440 000
Personnel costs (EUR million)	1 110 000
Value added (EUR million)	1 820 000
Gross operating surplus (EUR million)	708 000
Share in non-financial business economy total (%)	
Number of enterprises	8.8
Number of persons employed	22.8
Value added	29.3
Derived indicators	
Apparent labour productivity (EUR thousand per head)	64.0
Average personnel costs (EUR thousand per head)	41.0
Wage-adjusted labour productivity (%)	154.0
Gross operating rate (%)	9.8

Source: Eurostat (online data code: [sbs_na_ind_r2)

eurostat

Figure 8: Manufacturing statistics (source Eurostat[39])

38 World Economic Forum, 2020, The Future of Jobs Report, October 2020.
39 Eurostat, March 2020, https://ec.europa.eu/eurostat/statistics-explained/pdfscache/10086.pdf

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Table 1: Estimated reskilling effort in EU until 2025

Reskilling needs	Percentage according to WEF 2020	Manufacturing employees in EU	Estimated effort needed for reskilling (in Person Months)	Total estimated effort for reskilling (In Person Months)
Reskilling needs of less than 1 month	26,8%	7.646.551	0,5	**3.823.275**
Reskilling needs of 1 to 3 months	22,4%	6.391.147	2	**12.782.293**
Reskilling needs of 3 to 6 months	16,6%	4.736.296	4,5	**21.313.333**
Reskilling needs of 6 to 12 months	20,6%	5.877.572	9	**52.898.152**
Reskilling needs of more than 1 year	13,6%	3.880.339	15	**58.205.086**
Sum	**100%**	**28.531.905**	**-**	**160.063.987**

According to studies conducted by Mc Kinsey & Global institute " The Future of Work in Europe- 2020"[40], occupational category and potential net job growth 2018- 2030 have been predicted.

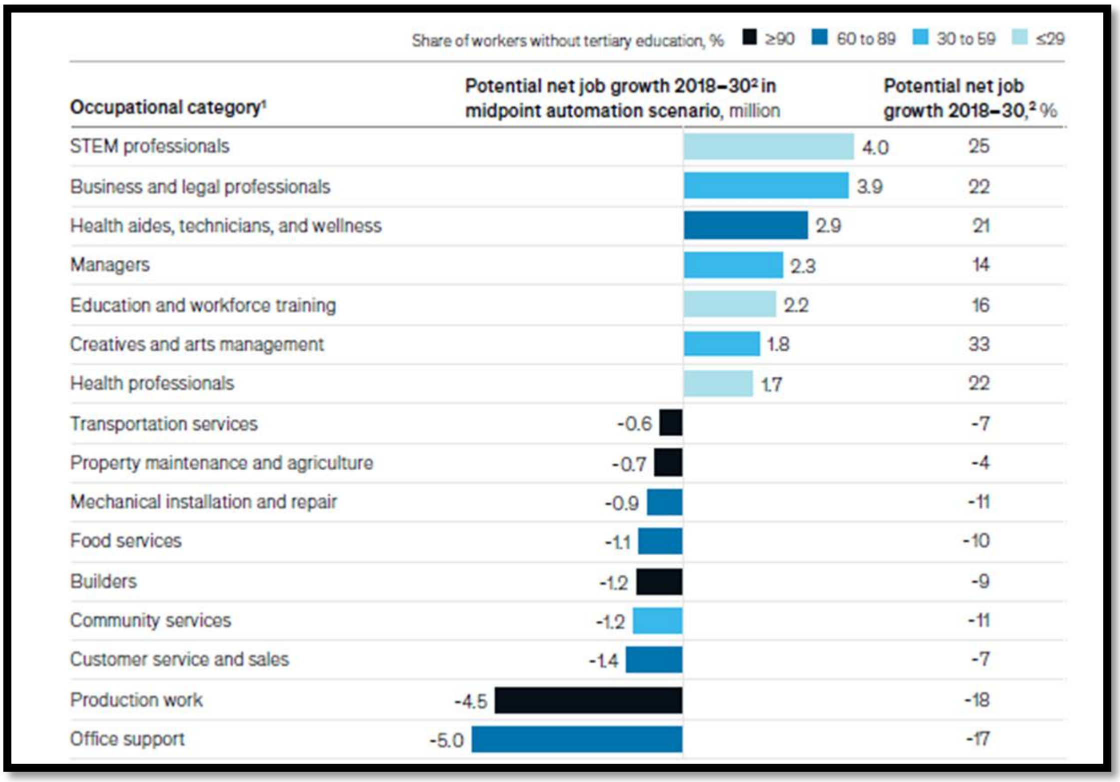

Figure 9 occupational category and potential net job growth 2018- 2030

40 https://www.mckinsey.com/featured-insights/future-of-work/the-future-of-work-in-europe

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As Figure 9 depicts, Across Europe, occupational category such as STEM professionals, Business and legal professionals, Healthcare workers are expected to grow significantly, while office support and production jobs could decline.

2.5 Overview of relevant initiatives

Following a research activity and stakeholder consultation, a set of initiatives aiming at learning and training in manufacturing have been collected and presented hereafter. However, the list presented below should not be considered as an exhaustive one but rather an indicative one.

- **Making our Workforce Fit for the Factory of the Future (FIT4FoF)** [41]: FIT4FoF project aims at addressing workers' needs, analyzing technology trends across six industrial areas of robotics, additive manufacturing, mechatronics/machine automation, data analytics, cybersecurity and human-machine interaction, to define new job profiles, which will inform education and training requirements. FIT4FoF will develop a further education and training framework, which places workers (women and men) at the center of a co-design and development process that recognizes and addresses their skills needs. The project has developed a catalogue with forty-four (44) (accessed in January 2021) digital upskilling initiatives.
- **Sector Skills Strategy in Additive Manufacturing (SAM)[42]:** The project aims to provide solutions capable of fostering and supporting the growth, innovation, and competitiveness of the Additive Manufacturing (AM) sector. The project has started in January 2019 and will run until 31st December 2022. The project has analyzed a set of professional profiles for additive manufacturing[43][44] that includes: 1) AM designer, 2) AM process engineer, 3) AM Inspector, 4) Inspector technical, 5) NDT technician, 6) AM supervisor, 7) AM coordinator, 8) Metrology Engineer, 9) Materials Engineer and 10) AM operator/technician.
- **BEYOND4.**0[45]: BEYOND 4.0 aims to help deliver an inclusive European future by examining the impact of the new technologies on the future of jobs, business models and welfare.
- **Pact for skills[46]:** The European Commission is launching a Pact for Skills, a shared engagement model for skills development in Europe. Companies, workers, national, regional and local authorities, social partners, cross-industry and sectoral organizations, education and training providers, chambers of commerce, and employment services all have a key role to play. The Pact was officially launched on 10 November 2020.
- **EIT Manufacturing[47]:** The industrial transformation that is taking place highlights the critical role of human capital. EIT manufacturing is aiming to educate and train the future and current industrial workforce according to market needs. EIT Manufacturing's education programmes provides innovative, customized and industry-driven knowledge and the ultimate skills in order to shape the future of manufacturing. In year 2020 EIT Manufacturing supported several activities in the area of education and skills development. These activities are:

41 www.fit4fof.eu
42 http://www.skills4am.eu/
43 https://skills4am.eu/documents/SAM%20D1.4%20Skills%20Roadmap%20VF.pdf
44 Stavropoulos et. al, 2020, Skills Requirements for the 4th Industrial Revolution: The Additive Manufacturing case, MATEC Web of Conferences 318, 01021 (2020) https://doi.org/10.1051/matecconf/202031801021ICMMEN 2020
45 https://beyond4-0.eu/
46 https://ec.europa.eu/social/main.jsp?catId=1517&langId=en
47 https://eitmanufacturing.eu/

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- **Engaging pupils into manufacturing- from valleys and local approach to the international level (EMBRYO):** EMBRYO project aims at drastically increasing the number of pupils interested in manufacturing studies.
- **Learning Factory in a Box:** The project aims to ignite the spark of curiosity for manufacturing in pupils. The image of the dirty and noisy factory has long since served its purpose. The manufacturing sector is highly technological and characterized by constant innovation. It needs young talents who can find their way in a digitalized world, handle it, and continue to innovate.
- **Young manufacturing leaders:** Young Manufacturing Leaders (YML) initiative aims to create a network of students and young people who will be mobilized as ambassadors of the manufacturing sector. These young people will spread awareness about the sector's importance and the evolution of manufacturing roles within local communities.
- **European Periphery Teaching Factory of the Future on Additive Manufacturing (PERFORM):** The project develops a demonstrator along with technical content to train students and upskill industry professionals in both metal AM and relevant cyber-physical technologies.
- **MirrorLabs – creating a similar learning environment for students all over Europe for human-robot coproduction:** The aim is the development of a common, easy-to-use ICT infrastructure for the existing equipment in the labs of the participating partners. The developed software is planned to be released open source so that it can be used by other partners within and outside EIT Manufacturing community.
- **Field Study Pedagogy:** The Field Study Pedagogy (FISP) project aims at designing a Teaching Factory methodology to deploy the training of engineering students on implementing innovation in manufacturing systems at bachelor and master levels.
- **Teaching Factory Knowledge Sharing Network (TF KNOWNET):** TF KnowNet aims to deliver a program where students, researchers and companies work together to mutually develop skills, promote and share expert knowledge through co-creating solutions to industrial manufacturing challenges.
- **LIFT European Network of Learning Factories:** The project builds a broad learning factories network ecosystem where research and technology transfer between academia and industry is fostered. LIFT aims at building up the skills of the future and ad-hoc training curricula to ensure the competitiveness of European manufacturing SMEs.
- **Simulation-based training for accident prevention in the automotive industry:** VR-SUSTAIN provides a training environment for students, trainees, and industry workers towards the prevention of accidents in manufacturing processes. Virtual Reality is applied to provide hands-on experience in an off-site environment for simulation-based training.
- **Network for Empowering People in Added-Value Manufacturing Systems and Technologies – Phase I:** The project aims to create from scratch a distributed Teaching and Learning Factory building on complementary Innovation Hotspots prioritized by each Factory Unit, using the respective manufacturing clusters as testbeds and pilot demonstrators, and strategically capitalize from and create synergies with ongoing Key Complementary Activities of each partner and its facilitating layer, as well as with local educational programmes.
- **Additive Manufacturing Teaching Factory**: EIT-AddManu will provide hands-on learning nuggets for teaching Additive Manufacturing (AM) in higher academic and industrial

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education. The targeted course work, which will be made available on the EIT Manufacturing Guided Learning Platform, contains tools for teaching AM in terms of design-tools, screening suitable AM systems and selecting the right material for the job.

- **Learning Factory to Implement Industry 4.0 in Machining:** Mach 4.0 is a training and learning activity that demonstrates the practical application of Industry 4.0 in machining processes. The program involves applying data analytics, big data, etc., to new manufacturing trends such as digital twin and zero defects manufacturing.
- **Nuggets on the digital transformation of work on the shop floor:** The course targets three distinct market segments: 1) Master students, especially the ones involved in honored programs; 2) graduated apprentices involved in specializing master programs; 3) managers and entrepreneurs in medium-sized and large firms.
- **The Smart Manufacturing Paradigm – A Tutorial Introduction on Cyber-Physical Production Systems:** The aim of this project is to make available for students, young researchers and overall practitioners didactic materials to educate them regarding the roots, expectations and challenges of the new technologies that are shaping the future of Industrie 4.0 and the smart manufacturing concept.
- **Teaching and Learning Nuggets for Interactive Robotics**: The project delivers hands-on, interactive experiences to encourage participation, cooperation and inclusion among students. It focuses especially on aiding teachers and trainers through companion teaching nuggets in order to apply new methodologies while delivering skills in key areas such as STEM subjects, robotics, entrepreneurship skills, and manufacturing.
- **Virtual Machina: Integration of VR-based simulation for students and workers' safe interaction and practice with machinery and robots: The Virtual Machina (V-Machina) project deals with the familiarization and training of students,** workers and practitioners working with industrial machinery and robots via Virtual Reality (VR). V-Machina consists in the creation of a learning environment that allows users to get a direct, immersive experience with selected activities related to the manufacturing sector.
- **Human in the AI loop**: The project "Human in the AI loop" is targeted to shop floor personnel (e.g. machine operators) as well as students and its main goal is to create the right competencies to work and collaborate with data-based artificial intelligence (DB-AI) systems.
- **Learning Nuggets for Robots and Physical Assistance in Manufacturing**: Industry partners and existing learning factories provide use cases from different business units and application areas. The learning factories in Vienna and associated learning factories will allow the production of nuggets in a controlled environment, testing of prototype content and practical exam.
- **Creating competences for Additive Manufacturing operators for powder material handling**: EMPOWDER programme aims to establish comprehensive training for Additive Manufacturing (AM) powder handling, to upskill the AM industry's workforce and add to its value. The online training programs under development in EMPOWDER will aid the progression of the AM industry's production which will have significant social impact by bringing flexibility to customizable mass production lines.

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3 Skills for the manufacturing of the future

3.1 Skills for Industry 4.0

Based on studies conducted in "2019- Curriculum Guidelines report" [48] in relation to **business environments**:

The target profile for Engineers for Industry 4.0 has five components:

i. Basic specialist knowledge in an engineering discipline
ii. Methodological skills, especially process-related and systems thinking
iii. Cross-discipline knowledge such as mechanical, electrical, and electronic engineering in computer sciences, data science, and respectively, basic knowledge of mechanical, electrical, and electronic engineering and data science for computer sciences
iv. Contextual knowledge, i.e., knowledge of conditions, requirements, and perspectives in other divisions and disciplines
v. Interdisciplinary skills, in particular teamwork ability, self-reliance, motivation, problem-solving skills, learning and adapting ability, transparency, and communication skills.

The whole profile relies heavily on specialist requirements in the various fields of engineering, with new analytical, computer science and data security skills being introduced. Engineers for Industry 4.0 must also be able to take views from other fields into account in their own work. The know-how and the ability to function both autonomously and in a team as well as the ability to learn and adapt are therefore crucial, particularly in terms of process thinking and system thought and inter-disciplinary abilities. These qualification criteria do not mean "super-engineers." Not all engineers have to possess the part in the target profile in the same way as the magnitude varies depending on the field of specialization.

3.1.1 Delivery mechanisms

Mechanisms for the provision of education apply to the means by which learners have access to education and education. They could provide personal service in which teachers/trainers and students connect face to face, electronically, and by mixed delivery (which includes a combination of methods).

Specific types of technology enabled learning include[49]:

E- and m-Learning: The dream of e-learning becomes a reality anytime everywhere with the enhanced economics of cloud computing. In addition, cloud resources such as shared folders and collaborative editing of documents allow groups of learners to collectively interact and to take on tasks instead of individually. M-learning has also opened up the option of smartphones' ubiquity. But the design and use of mobile devices prevents m-Learning from replicating e-Learning content.[50]

MOOCs and SPOCs: MOOCs quickly became popular, in particular because platforms such as EdX and Coursera as well as FutureLearn are increasing recognition. MOOCs allow hundreds of students around the world, typically adults, to study in a smooth way. Courses on the aforementioned sites are usually more theoretical since universities offer them. [51]

48 http://skills4industry.eu/skills-industry-curriculum-guidelines-40

49 PwC analysis incorporating multiple expert sources

50 https://www.opencolleges.edu.au/informed/features/the-ten-emerging-technologies-in-education-andhow-they-are-being-used-across-the-globe/
https://www.opencolleges.edu.au/informed/features/the-ten-emerging-technologies-in-education-andhow-they-are-being-used-across-the-globe/
https://elearningindustry.com/top-5-design-considerations-for-creating-mobile-learning

51 https://www.edx.org - https://www.coursera.org - https://www.futurelearn.com

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Games and gamification: Gaming-based learning proved a valuable training and encouragement tool and went beyond simply incorporating interactive and online games into curricula. Game-based interactions can be intuitively powerful in scaffolding principles and interactively simulate real-world experiences. [52]

Wearables, IoT and advanced learning analytics: Wearable electronics, embedded learning sensors and software-based learning performance monitoring are promising ways of improving and personalizing learning outcomes. [53]

Immersive technologies like Virtual and Augmented Reality (VR/AR) (including haptic technology, acoustic and visual elements) In the field of education, more and more are being discussed. It is important to remember, however, that creation of educational content in R&D is not merely a replication of 360 degrees in e-learning content. Usually, VR technology is best used to generate unusual, costly, dangerous, or empathic experiences.

3.2 From Industry 4.0 to Industry 5.0

Based on **Industry 5.0: Towards a sustainable, human-centric, and resilient European industry report**, Industry 5.0 recognizes the power of industry to achieve societal goals beyond jobs and growth to become a **resilient** provider of prosperity by making production respect the boundaries of our **planet and placing the wellbeing** of the industry **worker at the centre** of the production process.[54]

The skills for the future of manufacturing identified by the 2019 World Manufacturing Report are[55]:

- Digital literacy as a holistic skill to interact with, understand, enable, and even develop new digital manufacturing systems, technologies, applications, and tools.
- Inter-cultural and -disciplinary, inclusive, and diversity-oriented mindset to address new challenges arising from a more diverse manufacturing workforce
- Ability to use and design new AI and data analytics solutions while critically interpreting results
- Cybersecurity, privacy, and data/information mindfulness to reflect the rapidly increasing digital footprint of the manufacturing value chain
- Creative problem-solving in times of abundant data and tasks technological opportunities in smart manufacturing systems
- Ability to handle the increasing complexity of multiple requirements and simultaneous tasks
- A strong entrepreneurial mindset including proactiveness and the ability to think outside the box
- Effective communication skills with humans, IT, and AI systems through different platforms and technologies
- Ability to work physically and psychologically safely and effectively with new technologies
- Open-mindedness towards constant change and transformation skills that constantly question the status quo and initiate knowledge transfer from other domains

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[52] https://www.opencolleges.edu.au/informed/features/the-ten-emerging-technologies-in-education-andhow-they-are-being-used-across-the-globe/

[53] https://www.opencolleges.edu.au/informed/features/the-ten-emerging-technologies-in-education-andhow-they-are-being-used-across-the-globe/

[54] Romero, D., Stahre, J., Wuest, T., Noran, O., Bernus, P., Fast-Berglund, Å., Gorecky, D.: Towards an operator 4.0 typology: a human-centric perspective on the fourth industrial revolution technologies. In: Proceedings of the International Conference on Computers and Industrial Engineering, pp. 1–11 (2016).

[55] World Manufacturing Forum's ten skills for the future of manufacturing © World Manufacturing Forum - https://worldmanufacturing.org/

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3.3 AI in Manufacturing: a worldwide analysis of required skills (WMF)

A further research conducted in the " 2020 World Manufacturing Report" on specific skills needed to work with AI was projected to dramatically revolutionize the manufacturing sector in artificial intelligence. According to Tractica's latest study, anniversary investors worldwide are expected by $2.9 billion in 2018 to $13.2 billion by 2025 on AI software, hardware, and manufacturing service. More organizations consider AI to be necessary if their competitive advantage is to be obtained or maintained. This transition would, however, pose important challenges, such as repercussions for the employees and the need for quality data to power AI systems. In addition, a number of ethical concerns surrounding AI have to be dealt, in order to promote sustainable adoption of AI. Based on the relation of this issue to companies as well as the broader manufacturing community, the 2020 World Manufacturing (WMF) report concentrated on the development of the manufacturing sector in the AI era.

3.3.1 Changing roles and new roles

The manufacturing transition with the implementation of AI has major effects on the positions and abilities of workers in the industry. It stressed the crucial role played by people to redefine the strategy of the organization. When the strategy is defined, the requisite steps for the transition are to be planed and assessed by other people. New functions and profiles are designed for the design, execution, operation, and maintenance of new AI applications during their life cycle. In a new organization of human and artificial intelligences, people can eventually interpret deeply changed positions. Such functions will be defined by the improvement of the conventional collection of competences, which both include improving foundational competences and core competences in the manufacturing sector and learning new data and AI skills. Figure 10 depicts ten Emerging jobs and top ten skills based on World Economic Forum report.

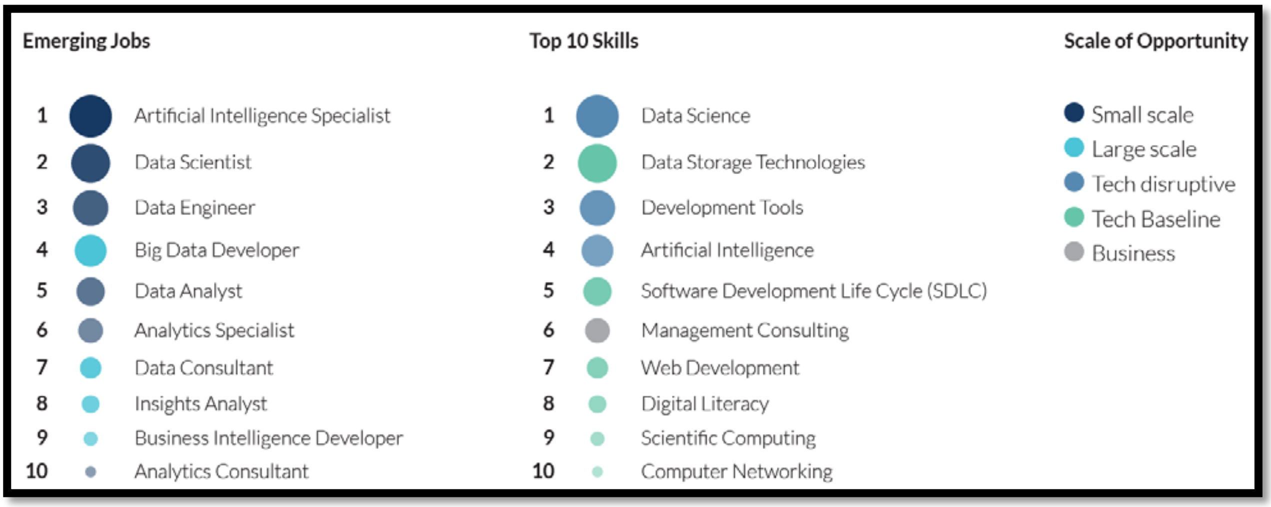

Figure 10 World Economic Forum- Emerging Jobs and Top 10 Skills

According to the Figure 10 Job profiles that have emerged can create opportunities in different scales, for instance; Data analyst and Analytics specialist in **Tech disruptive scale**, Analytics consultant in **business scale**, Artificial intelligence specialist, data science and data engineers in **small** and other job profiles in **large scale** can create opportunities. There are similar conditions for the top 10 skills, the most important ones which can mentioned are **Management consulting in Business scale**, **Data science, Development tools and**

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artificial Intelligence in Tech disruptive scale and Data storage Technologies, Software development Life cycle in Tech baseline scale, etc.

3.3.2 Skills needed to work with AI

Based on classification of WMF 2020, five main relevant skills which are needed to work with Artificial Intelligence were identified. Figure 11 displays these categories.

Figure 11 Categories of skills needed to work with AI (2020 World Manufacturing Report)

1. **Foundation skills**: Data literacy is becoming increasingly important in the workplace and in everyday life, as well as in core AI literacy[56]. The development of fundamental skills is thus essential if the role of an AI-enabled future manufacturing is to be fertile ground for the development and continuous improvement of technical competences and ethical skills.
2. **Core manufacturing skills**: Manufacturing staff will still require strong expertise in the core sectors, such as use of advanced materials, creative shapes, design and advanced technology to deliver the best quality service. Manufacturing would also still require the expertise and skills required for design, management and innovation of processes, research and development, production, quality, maintenance, logistics and supply chains, related to the processes and systems involved in manufacturing.
3. **AI skills**: The opportunity provided by AI in manufacturing would require new technological and management skills. Understanding the functioning, learning and communicating of AI-based Systems with customers, recognition of possibilities and where AI could be used within the enterprise to revisit current company processes to enhance performance would be crucial.

[56] *Wong, G. K., Ma, X., Dillenbourg, P., & Huan, J. (2020). Broadening artificial intelligence education in K-12: where to start? ACM Inroads, 11(1), 20-29.*

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4. **Skills for trustworthy AI**: According to the EU, trustworthy AI should be lawful, ethical, and robust, both from a technical perspective while considering its social environment[57]. New skills are necessary to shape AI's purpose responsibly in terms of people, businesses, and companies to achieve a tangible growth, implementation and utilization of the AI system that meets the trustworthy AI requirements. These competences can be fostered by developing special AI courses and/or incorporating into existing technical AI courses principles, methods, and tools for dealing with human agency and oversight, technical robustness and safety, privacy and data governance, etc.
5. **Transversal skills**: In addition to modern or advanced technical-professional skills, manufacturing employees need transversal skills - such as strictly human innovation and entrepreneurship, personal and social skills - which will increase value in the future, as they are not yet readily available in AI but can be replicated.

[57] *High-Level Expert Group on Artificial Intelligence (2019). ETHICS GUIDELINES FOR TRUSTWORTHY AI. Retrieved from: https://ec.europa.eu/futurium/en/aialliance-consultation*

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4 Future Skills Matching with CF1 Pathways (6Ps People dimension)

Chapter 2 has highlighted that the concern toward the future skills is mainly converging in the digital domain. The 2020 WMF Report and the 2020 WEF Jobs of tomorrow suggest that the digitalisation process does not refers to technologies and processes but must encompass also a proportionate empowering of digital skills at every level (from shopfloor to top management) and eventually a creation of roles aligned to the digital advancement that industry is facing. In light of this, a metrics aimed at measuring which skills are needed and how much developed must be at every level of an organisation seems to be fundamental element to transform the suggestions articulated into practice.

In this sense, POLIMI, within the H2020's MIDIH Project, has developed a structured methodology aimed at supporting manufacturing companies in defining it current level of digital maturity, identifying the desired level of digital maturity to reach in a given time horizon and consequently structuring a digital transformation roadmap to achieve the goals set.

This methodology, called 6Ps Migration Model, is organised according to 6 dimensions (the Ps), 3 belonging to the technical area (Product, Process, Platform) and 3 belonging the socio-business area (People, Partnership, Performance). All together are meant to identifying the most suitable strategy to ensure the successful digital improvement mentioned above as well as identifying the right tools and services propaedeutic to concretely reach the results.

This chapter has the aim of presenting in detail the 6Ps MM's People dimension.

Figure 12 6Ps Digital Transformation Tool

In particular, People dimension aims at assessing the skills owned or to be owned among manufacturing SMEs' human capital. This dimension is not divided into 6 areas directly, due to the high variance in the roles operating in the sector, this pillar has been at first divided into 3 macro-professions, namely: Operators & Technicians, Professional & Engineers and Managers & C-Levels. However, 6 the six areas of the model have been defined. These areas are: *Industry 4.0 Strategy* to measure the level of awareness about industry 4.0 and involvement into activities aimed at implementing Industry 4.0 solutions; *Smart Autonomous Factories* to evaluate o which extent digital technologies are exploited in favor to traditional tools in running operations; *Hyperconnected Factories* to assess the level of digitalization of tools and skills exploited in this field, *Collaborative Product-Service Factories* to evaluate the skills and tools utilized in the product development phase, *Industry 4.0 Infrastructure* to assess the level of skills in the field of Industry 4.0

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Technologies (either Information Technologies and Operations Technologies) available within the fir and *Big Data* to assess the level of skills in the field of big data.

Industry 4.0

		LEVEL-1 INITIAL	LEVEL-2 MANAGED	LEVEL-3 DEFINED	LEVEL-4 INTEGRATED	LEVEL-5 EXPLOITED
INDUSTRY 4.0 STRATEGY	MANAGER	Know and understand the trends related to Industry 4.0 and changes in the competitive environment	Analysing the transformation of the value chain by adopting Industry 4.0	Provide leadership for the creation of an Industry 4.0 strategy and include risks and opportunities	Forge relationships and alliances with the various stakeholders of the Industry 4.0 ecosystem	Apply strategic thinking, stakeholder management and organizational leadership to develop and implement an integrated strategy to exploit the capability of I4.0 technology to improve the business
SMART OPERATIONS	OPERATOR	Use standard HMI	Use wearable devices to monitor production	Analytical skills to interpret production data	Use of new production tech. (e.g. collaborative robotics, 3D printing etc.)	Plan, monitor, analyse information, inspect (with AR) determine causes of problems/failures and perform corrective actions
	PROF/MNG	Use of common software (e.g. excel)	Use of Enterprise Systems (ERP MES PLM)	Analytical skills to analyse production data autonomously and interpret production data	Redesign processes end-to-end to improve their performance through I4.0 technologies	Plan, coordinate, optimize smart production systems
SMART SUPPLY CHAIN	OPERATOR	Use of common software (e.g. excel)	Use of wearable devices	Analytical skills to interpret data	Use/interaction of new smart warehouses, picking and automatic guided vehicles	Plan, monitor, analyse information, inspect (with AR) determine causes of problems/failures and perform corrective actions
	PROF/MNG	Use of common software (e.g. excel)	Dynamic management in real time through monitoring and tracking technologies	Collaborate with different external actors and integrate them in the digital supply network	Analyse market demand, supply network data, social media and other data, and predict future scenarios	Plan, coordinate, optimize the collaborative digital supply network
SMART PRODUCT-SERVICE ENGINEERING	TECHNICIAN	Use of technical drawing programs (CAD)	Drawing in 3D	User skills for 3D printing AR/VR	Design of smart products (integration of sensors, antennas, chips and other components)	Model-based design and Simulations
	PROF/MNG	Product-oriented organization and business models	Understanding the importance to follow the whole lifecycle of the Product and support services	Design smart products customized through sw user interface and services, integration with the enterprise IT systems	Design and management of the product-service lifecycle and Business Models	Open innovation of smart PSS lifecycle and B.M. with a digital ecosystem of partners.
INDUSTRY 4.0 INFRASTRUCTURE (IT_OT)	PROF	Contribute to the design and general functional specification and interfaces	Use of modelling languages and programming tools	Evaluation of pros and cons of different sensors, software, protocols and select the most adequate to the needs of the enterprise (including cybersecurity)	Specify, refine, update and make available a formal approach to implement solutions, necessary to develop and operate the architecture oriented towards Industry 4.0	Investigating latest technologies and devising innovative solutions for integration of new technology into existing systems to meet future business Industry 4.0 requirement
BIG DATA	PROF	Selecting and collecting useful data	Cleaning, organising and rationalising the data	Selecting and implementing technology for analysing big data	Clean business insights from big data (algorithms)	Using big data creatively and innovatively

Figure 13 Overview of the structure of 6Ps MM's People dimension

As shown in Figure 13, People dimension has been clustered into 3 sub-dimensions, one for each macro-profile typically present in a manufacturing firm. Hence, the 3 sub-dimensions identified are: Blue-collar workers which include operators and technicians, Managers & C-levels and Professional & Engineers.

4.1 Blue-collar Workers dimension

This first category has the objective to assess the level of digital maturity achieved and to be reached by operators and technicians within the manufacturing firm. In particular, the level of digital maturity in this case is measured according to 2 main criteria which are: the level of digital skills of the workers related to the use of digital tools and secondly the actual adoption of digital tools and functionalities by the blue-collars workers.

The areas of People dimension through which this macro-profile of workers is assessed are: Smart Autonomous, Hyper-connected and Collaborative Product-Service Factories of the Future.

In Smart Autonomous Factories area, the objective is to measure which tools are equipped the workers with to carry out core activities for the firm (e.g., production). In parallel, it is assumed that the reliance on specific digital tools also reflects a comparable level of digital skills to use these latter, or rather, the operators have been trained to use them. Hyperconnected Factories area is designed to assess the level of digital maturity of tools and skills owned by blue-collars in order to perform supply chain-related tasks and coordinate with upstream and downstream tiers. The description of the level of digital maturity described below apply for both the areas presented so far.

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Level 1, INITIAL, refers to a scenario in which blue-collars have been equipped with standard tools to carry out their activities and report advancement or failure in the operations (e.g. task performed or defect detected). **Level 2** refers to a scenario in which blue-collars are equipped with wearable tools aimed at performing similar task described in level 1. Example in this sense could be, visors of wearable scanners. From **level 3** the workers are not only equipped with specific tools to perform standard activities, but they have been also properly trained to analyse production data from the shopfloor and autonomously find potential deviations and set minor corrective actions. In **level 4** the level of advancement of technologies used by operators increases significantly. In this scenario, the worker is meant as an operator 4.0 supported by Industry 4.0 solutions. Finally, **level 5** refers to operators 4.0 trained to use the most advanced solutions and autonomously monitor and interpret data from shopfloor, identify potential failure, causes and set corrective actions and plan production task.

Regarding Collaborative Product-Service Factories, the objective of the 6Ps model is to evaluate the level of digital maturity (AS-IS and TO-BE) of those processes linked to the development and then management of new PSS offered by the manufacturing firm to the market.

In particular, Level 1 refers to a scenario in which the operators are provided and consequently trained to develop the product only with traditional drawing tools like CAD. Level 2 identifies a scenario in which operators are able to design PSS also through 3D standards like AutoCAD. In level 3, some advanced technologies are implemented like VR/AR to virtualise the product or 3D printing for rapid prototyping. Level 4 applies for those firm that provide a smart PSS and so design it by integrating it with sensors, chips and other smart components. Finally, level 5 describes a scenario in which operators are able to carry out advanced and complex multi-based design and perform simulations on PSS's functionalities.

4.2 Professionals and Engineers dimension

This third and last category has the objective to assess the level of digital maturity achieved and to be reached by Professionals and engineers within the manufacturing firm. Even for this category, the level of digital maturity in this case is measured according to 2 main criteria which are: the level of digital skills of the managers related to the use of digital tools and secondly the actual adoption of digital tools and functionalities.

The areas of People dimension through which this macro-profile of workers is assessed are: Smart Autonomous Factories, Hyperconnected Factories, Collaborative Product-Service Factories, Industry 4.0 infrastructure and Big Data.

In line with the definition provided in paragraph 3.2, in Smart Autonomous Factories area, the objective is to measure which tools are equipped the managers with to manage operations. Again, it is assumed that the reliance on specific digital tools reflects also a comparable level of digital skills to use these latter, or rather, the managers have been trained to use them.

Level 1, INITIAL, refers to a scenario in which professionals rely on very simple tools (e.g. excel sheets, shared folders etc.) to manage operations. With level 2 the operations are monitored and managed through Enterprise Systems (e.g. ERP, MES, PLM etc,) integrated one to each other. With level 3, professionals are able to monitor and analyse production data autonomously and consequently are able to set corrective actions independently. From level 4, professionals are able to re-design operations processes in order to achieve a better optimization of performances and integrate Industry 4.0 technologies. Finally, level 5

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describes a scenario in which professionals are able to plan, monitor and optimize in an integrated way the smart plant.

In line with the definition provided in paragraph 3.2, Hyperconnected Factories area is designed to assess the level of digital maturity of tools and skills owned by managers in order to manage and coordinate manufacturing firm's supply chain and cooperate with upstream and downstream tiers.

Level 1 refers to a scenario in which professionals rely on very simple tools (e.g. excel sheets, shared folders etc.) to manage the supply chain. Level 2 describes a scenario in which the firm has implemented solution allowing real-time monitoring and Track & Trace. Hence real-time management of the Supply Chain is allowed as well. From level 3 the technical profiles are able to design firm's processes in order to permit a solid collaboration among Supply Chain partners. Level 4 is applied for those firms that are able to collect, analyse and exploit indirect data to plan their supply chain (e.g. weather, market trends, social media etc.). Finally, level 5 is assigned to those realities in which the firm is able to constantly plan and monitor its supply network through a collaborative approach with upstream and downstream tiers.

Similarly, to the definition reported in paragraph 3.1 and 3.2, the objective of the Collaborative Product-Service Factories area is to evaluate the level of digital maturity (AS-IS and TO-BE) of those processes linked to the development and then management of new PSS offered by the manufacturing firm to the market.

Level 1 identifies those firms organised according to a Product-oriented approach and the business model is so strictly related to the provision of the product itself rather than its functionalities. Level 2 refers to those firms in which the technical profiles are focused on the analysis of the whole Lifecycle of the PSS already in the designing phase. Level 3 is applied for those companies that develop customised PSS and in doing this rely on specific advanced software user interfaces. Lin level 4 the professionals are devoted to the design of the PSS offered by the manufacturing firm by taking into account the whole lifecycle of this latter. Hence, in this scenario, also the business model around the PSS is taken into consideration since the design phase. Finally, level 5 refers to those firms that are able to set open systems for the collaborative design and development of PSS with relevant partners.

Industry 4.0 infrastructure is focused on the level of digital maturity of the firm in terms of adoption of Industry 4.0technologies aimed at supporting and managing the overall corporate infrastructure.

Level 1 refers to a scenario in which professionals do not analyse in detail the different features of technologies 4.0 implemented or to be implemented by the firm but simply provide a general contribution needed to adapt these latter to company's requirements. In this sense, the IT and OT overall infrastructure turns out to be poorly optimized at global level. In level 2, the manufacturing firm has the capability to develop internally on-premises solutions that better suit its needs. In particular, the professionals are trained and able to use modelling languages and programming tools. From level 3, professionals usually carry out comprehensive evaluation of different Industry 4.0-related solutions aimed at identifying pros and cons of each technology and consequently select the most suitable according to the actual needs of the firm. Level 4 refers to a scenario in which there is a formal approach adopted when selecting the right Industry 4.0 solution to implement. Starting from this level, professionals are also meant to be properly skilled to customise the solutions available in the market and better fit enterprise needs. Finally, level 5 is applied for those companies that are devoted to the implementation of the most advanced Industry 4.0 technologies with a greater attention on future business requirements rather than its current needs.

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The last area, Big Data, has in turn the aim of assessing the level of skills of professionals and digital maturity of the manufacturing company for what concerns the approach in managing and exploiting useful data.

Level 1 identifies a scenario in which the firm is able to select and collect data from the shopfloor, but not specific analytical tools are implemented. In level 2 data are also cleaned and controlled, organised according to given patterns and clustered according to company's objectives. From level 3 the enterprise is able not only to select, collect, clean and rationalise data, but it has also implemented specific analytical tools aimed at exploiting them for more complex decision-making processes. Level 4 refers to a scenario in which the firm, due to algorithms, is able to exploit the data collected to autonomously extract knowledge and business insights. Finally, level 5 is referred to those realities in which the firm has the capability to collect and exploit Big Data according to the current state-of-the-art and in a customised way.

4.3 C-levels Executives and Managers dimension

This second category has the objective to assess the level of digital maturity achieved and to be reached by middle and top managers within the manufacturing firm. Even for this category, the level of digital maturity in this case is measured according to 2 main criteria which are: the level of digital skills of the managers related to the use of digital tools and secondly the actual adoption of digital tools and functionalities.

The areas of People dimension through which this macro-profile of workers is assessed are: Industry 4.0 Strategy, Smart Autonomous Factories, Hyperconnected Factories and Collaborative Product-Service Factories.

Regarding Industry 4.0 Strategy area, the aim is to evaluate how and to which extent Industry 4.0 is a driver in the definition of corporate strategy and on the other hand how and to which extent corporate strategy integrates the transition toward 4.0 paradigm.

In this sense, Level 1 refers to a scenario in which managers are aware of the main trends related to Industry 4.0 as well as the competitors initiatives aimed at achieving a digital transformation. From level 2 the scope of the analysis of managers is extended to the whole Supply Chain, hence level of adoption, benefits and costs are analysed also at a more integrated level. At level 3, the manufacturing firm is able not only to evaluate the impact of Industry 4.0 projects on the Supply Chain but also is capable of driving such transitions. In this stage, Industry 4.0 becomes a key driver of manufacturing firm's strategy. Level 4 identifies a scenario in which the transition toward Industry 4.0 is fostered by the creation of strategic partnership with relevant stakeholders. In this sense, the 6Ps MM has considered: DIHs, Research and Innovation centres, Training and Education institutions, IT Solution Providers, Suppliers and Customers. Finally, level 5 describes a scenario in which Industry 4.0 is posed at the centre of corporate strategy and face und a Supply Chain perspective.

In Smart Autonomous Factories area, the objective is to measure which tools are equipped the managers with to manage operations. Again, it is assumed that the reliance on specific digital tools reflects also a comparable level of digital skills to use these latter, or rather, the managers have been trained to use them.

Level 1, INITIAL, refers to a scenario in which managers rely on very simple tools (e.g. excel sheets, shared folders etc.) to manage operations. With level 2 the operations are monitored and managed through Enterprise Systems (e.g. ERP, MES, PLM etc,) integrated one to each other. With level 3, managers are able to monitor and analyse production data autonomously and consequently are able to set corrective actions independently. From level 4, managers are able to re-design operations' processes in order to achieve a better optimization of performances and integrate Industry 4.0 technologies. Finally, level 5 describes a scenario in which managers are able to plan, monitor and optimize in an integrated way the smart plant.

Hyperconnected Factories area is designed to assess the level of digital maturity of tools and skills owned by managers in order to manage and coordinate manufacturing firm's supply chain and cooperate with upstream and downstream tiers.

Level 1 refers to a scenario in which managers rely on very simple tools (e.g. excel sheets, shared folders etc.) to manage the supply chain. Level 2 describes a scenario in which the firm has implemented solution allowing real-time monitoring and Track & Trace. Hence real-time management of the Supply Chain is allowed as well. From level 3 the management is able to design firm's processes in order to permit a solid collaboration among Supply Chain partners. Level 4 is applied for those firms that are able to collect, analyse and exploit indirect data to plan their supply chain (e.g. weather, market trends, social media etc.). Finally, level 5 is assigned to those realities in which the firm is able to constantly plan and monitor its supply network through a collaborative approach with upstream and downstream tiers.

Similarly, to the definition reported in paragraph 3.1, the objective of the Collaborative Product-Service Factories area is to evaluate the level of digital maturity (AS-IS and TO-BE) of those processes linked to the development and then management of new PSS offered by the manufacturing firm to the market.

Level 1 identifies those firms organised according to a Product-oriented approach and the business model is so strictly related to the provision of the product itself rather than its functionalities. Level 2 refers to those firms in which the management is focused on the analysis of the whole Lifecycle of the PSS already in the designing phase. Level 3 is applied for those companies that develop customised PSS and in doing this rely on specific advanced software user interfaces. Lin level 4 the management is devoted to the design of the PSS offered by the manufacturing firm by taking into account the whole lifecycle of this latter. Hence, in this scenario, also the business model around the PSS is taken into consideration since the design phase. Finally, level 5 refers to those firms that are able to set open systems for the collaborative design and development of PSS with relevant partners.

4.4 Preliminary Validation of the 6Ps People dimension

As mentioned above the 6Ps methodology has been developed by POLIMI within MIDIH project. Hence, it has been validated in all its dimensions through the project's pilots.

Focusing again on People dimension, not all the pilots have experienced an increase in digital maturity referred to People dimension that could be directly linked to the activities carried out within MIDIH. For this reason, the 6Ps methodology has not been exploited to assess the increase abovementioned nor to develop a digital transformation roadmap. However, the manufacturing SMEs impacted in this dimension have recorded at least 1 level improvement in one area. It is worth noticing that since the target of the project were SMEs, the initial (AS-IS) status reported as well as the level of digital skills turned out to be quite heterogeneous and sometimes hard to be assigned to level 1 due to the almost absence of concern toward the topic.

However, with the development of an action plan able to consider multi-dimensional (multi-Ps) digital transformation projects, the overall level of digital maturity after MIDIH (TO-BE) reached level 2.9 on average from an initial mean level equal to 1.7.

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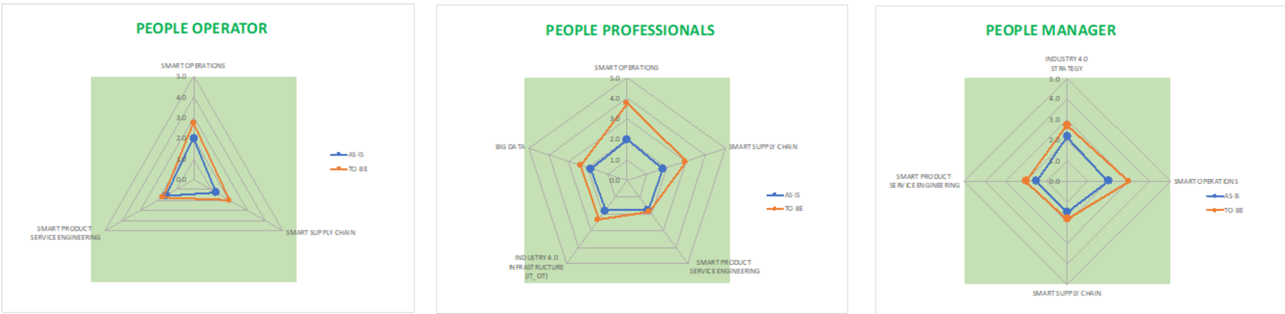

Figure 14 Results of 6Ps methodology's People dimension in MIDIH

Similarly, the 6Ps methodology has been adopted also on another EU funded project, namely BOOST4.0, and applied in all its dimensions. In this second experimentation, the focus has been again on manufacturing companies. Even in this case, the methodology has been applied to only those firms that have been clearly impacted by project's solutions. Hence, increases in digital maturity motivated by exogenous factors (e.g. independent growth of the firm and related structure) have not been taken into account nor assessed.

The companies tested during BOOST 4.0 project proved to have an overall higher level of digital maturity in the field of People with an AS-IS (before-BOOST) level equal to 2.2. However, once implemented a tailored 6P's digital transformation roadmap, this average level has been successfully increased to 3.0 thus gaining almost 1 level overall.

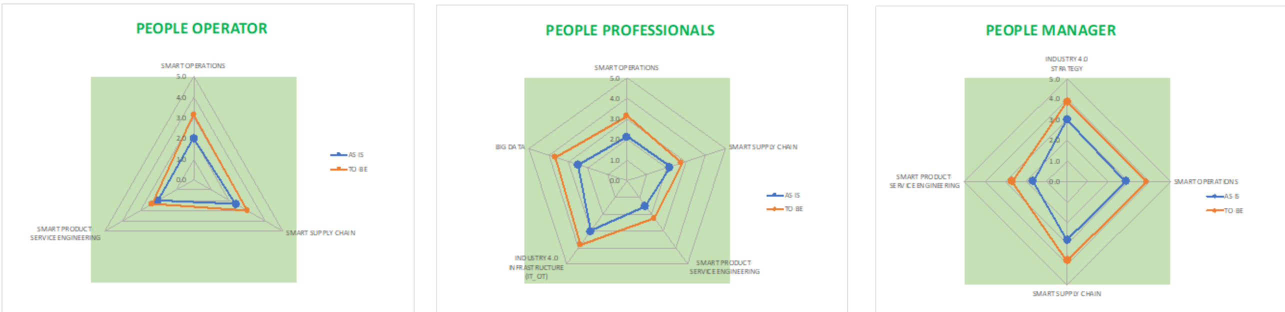

Figure 15 Results of 6Ps methodology's People dimension in BOOST4.0

In order to validate the methodology at process industry level, the 6Ps methodology has been applied also in another EU funded project, CAPRI. As for the ones mentioned above, even in this case the assessment covered all the six dimensions. As anticipated, MIDIH and BOOST4.0 addressed companies operating in the discrete manufacturing industry while CAPRI was devoted to those operating in the process manufacturing (e.g. asphalt, pharma etc.) hence, some adjustments to the methodology have been required.

In line with the previous validations, the assessment has focused only on those improvement in the level of digital maturity that have been deemed due to the direct impact of project's solutions.

In particular, at global level the digital maturity index referred to People dimensions have been successfully increased by roughly 1 point, from 1.2 to 2.2. The operative and tactical profiles, namely Operators & Technicians and Professionals & Engineers, turn out to be those impacted the most with an average increase on respectively 1.2 and 1.1 levels.

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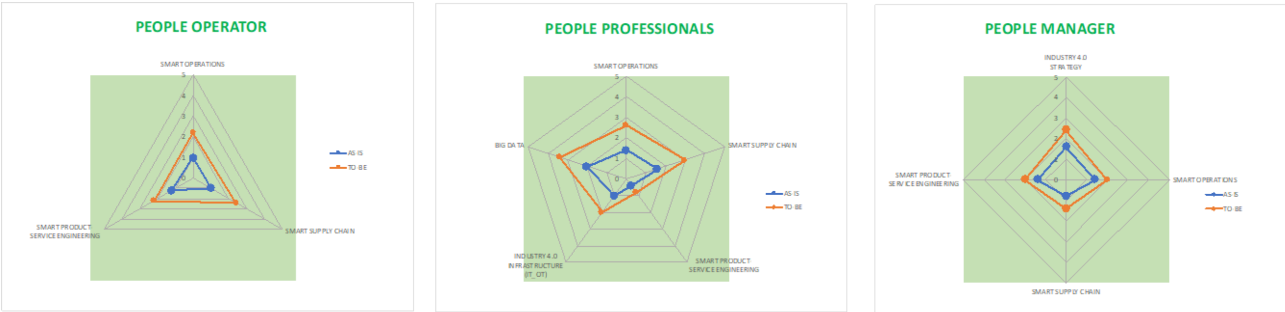

Figure 16 Results of 6Ps methodology's People dimension in CAPRI

Further validation of the whole 6Ps method (online survey) and the People dimension in particular will be performed on DT-ICT-07-2018 Innovation Actions in second half 2021, as soon as they have achieved a consistent maturity of their Industrial Pilots. Further validations are foreseen in 2022 inside the DT-ICT-07_2019 DMP innovation actions and I4MS Phase IV projects: they will be reported in the next edition of this deliverable D4.3 at M30.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 873086.

5 Professions and Skills Analysis for CF2 Pathways

While Chapter 4 has analysed skills needs for three categories of employees (workers, engineers, managers) engaged in the three CF1 pathways (Smart Autonomous, Hyper-connected, Collaborative Product-Service Factories), in this chapter we are conducting an analysis of needs for new professions and skills (mentioned in chapter 3) required by the CF2 pathways (Data Spaces, Circular Economy, Cyber Security).

5.1 Roles and Professions for Data Sharing pathway

Related to roles and professions in Industry 4.0, a structured repository of 100+ technical and managerial skills 4.0 covering five areas[58] necessary to define Industry 4.0 strategies, and design, manage and enable Industry 4.0 processes and business models which are:

- Smart product-service design management
- Smart Hyperconnected Factories management
- Smart Autonomous Factories management
- IT-OT integration management
- **Data science management**

In the case of "**Data science management**", five main job profiles and their related competencies validation are defined[59] , which Figure 17 depicts them:

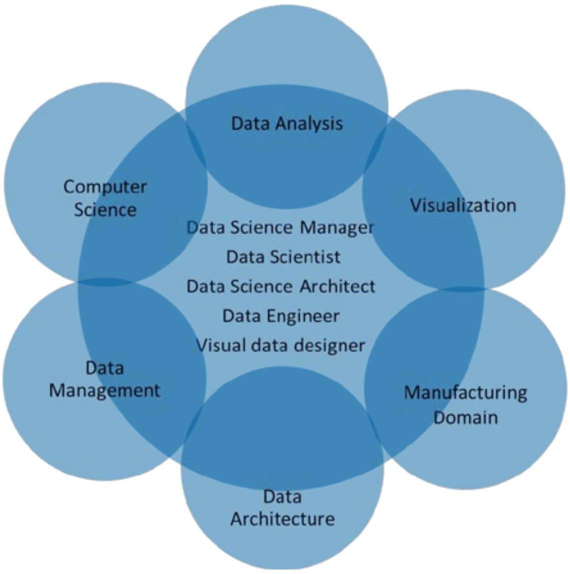

Figure 17 Job profiles and competencies validation

5.1.1 The 5 roles and Professions and their skills

1- **Data Science Manager.** Data Science Managers propose, plan, and manage functional and technical evolutions of the data science operations within the relevant domain. Top related skills for this position are as follows:

- knowledge about data processes

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- knowledge about business processes
- knowledge about performance indicators
- communication with domain experts
- ability to manage the data science team and resources
- ability to develop and execute the data strategy according to business objectives

2- **Data Scientist**. Data scientists find, interpret, and merge data sources, manage large amounts of data, ensure consistency of datasets, and create visualizations to aid in understanding data. Build mathematical models, present, and communicate data insights and findings, and recommend ways to apply the data. Top related skills for this position are as follow:

- ability to identify and interpret relevant data sources
- ability to use a programming language (R, Python)
- knowledge about advanced mathematical and statistical models
- use of machine learning
- use of Bayes classifier
- use of Deep Learning techniques
- use of Operational Research methods
- use of optimization algorithms
- knowledge about domain-specific processes
- ability to communicate with domain experts

3- **Data Science Architect**. Data Science Architect designs and maintains the architecture of data science applications and facilities. Top related skills for this position are as follow:

- ability to integrate data universe
- knowledge about big data architectural standards
- ability to select software platforms for big data (Hadoop, Data Lake)
- ability to select hardware platforms for big data (performances, costs, scalability, flexibility)

4- **Data Engineer**. Data Engineers build, manage, and maintain data pipelines. Top related skills for this position are as follow:

- ability to develop data models and workflows
- ability to use cloud computing
- knowledge about data storage and query languages
- ability to maintain security, quality, integrity, safety, and availability of data
- ability to integrate new data technologies into existing systems

5- **Visual Data Designer**. Data Visualization Designers create custom visualizations from complex data sets in a compelling way. Top related skills for this position are as follow:

- ability to create infographics (maps, charts, diagrams)
- ability to visualize the huge and complex volume of data
- ability to understand complex information
- ability to develop insightful and engaging data analytics view
- ability to develop vector graphics, scientific illustrations, and icons (maps, charts, diagrams)
- ability to develop interface and interaction to increase user experience
- user experience analysis, design, and evaluation

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5.1.2 First results of skills prioritisation in BOOST4.0 Lighthouse project

To determine the priority and importance of the mentioned skills for each job profile in the project's Pilots, online questionnaires were designed and published in BOOST4.0 project's General Assembly (G.A. meeting – July 2019 – Lisbon), results are as follow:

5.1.2.1 Data Science Manager

Figure 18 shows the opinions of participants in BOOST4.0 (G.A. meeting – July 2019 – Lisbon) related to skills of " Data Science Manager ":

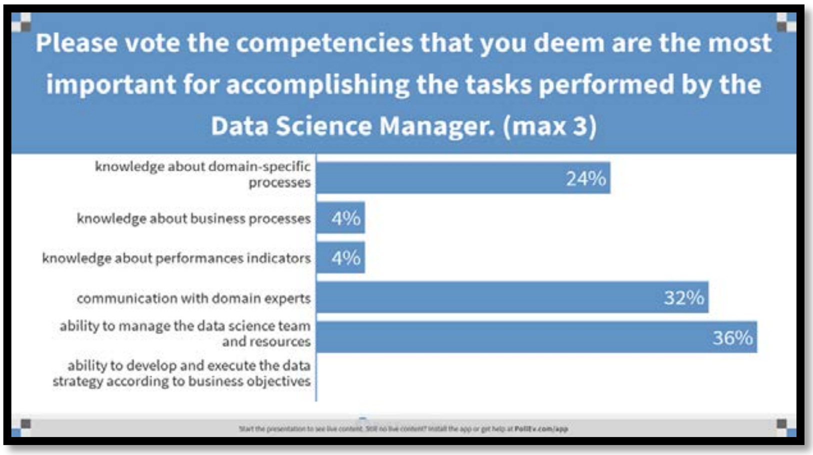

Figure 18 Skills of Data Science Manager

Figure 18 indicates 36% of participants believe that ability to manage the data science team and resources is the most important skill of data science manager, which also they need or possess in their pilots and exactly in the opposite side, ability to develop and execute the data strategy according to business objectives does not have importance in this job position for them.

5.1.2.2 Data Scientist

Figure 19 shows the opinions of participants in BOOST4.0 (G.A. meeting – July 2019 – Lisbon) related to skills of "**Data Scientist**":

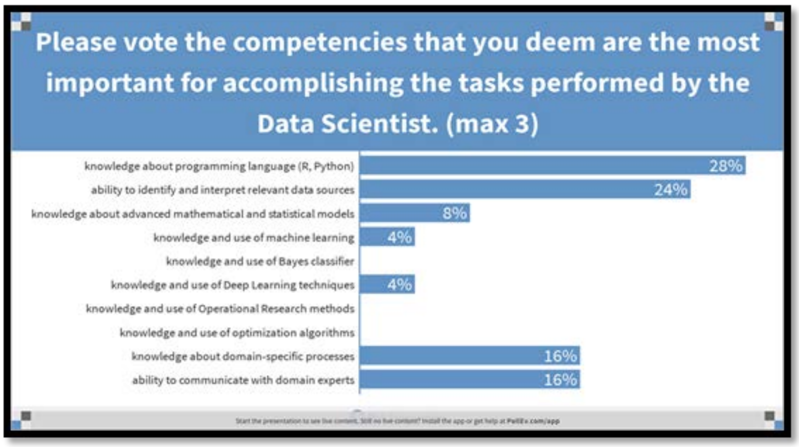

Figure 19 Skills of Data Scientist

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 873086.

Figure 19 indicates that knowledge about programming language and the ability to identify and interpret relevant data sources have a high priority for pilots but Knowledge and use of Bayes classifier, operational research methods, and optimization algorithms are skills which are not important in this job position for them.

5.1.2.3 Data Science Architect

Figure 20 shows the opinions of participants in BOOST4.0 (G.A. meeting – July 2019 – Lisbon) related to skills of "**Data Science Architect**":

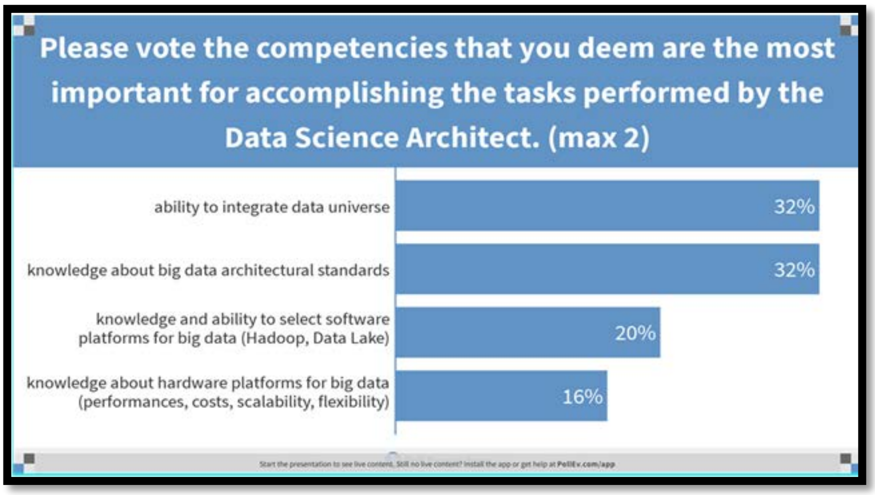

Figure 20 Skills of Data Science Architect

Figure 20 depicts that knowledge about big data architectural standards and the ability to integrate data universe has a high priority for pilots but Knowledge about hardware platforms for big data is a skill which has low priority in this job position for them.

5.1.2.4 Data Engineer

Figure 21 shows the opinions of participants in BOOST4.0 (G.A. meeting – July 2019 – Lisbon) related to skills of "**Data Engineer":**

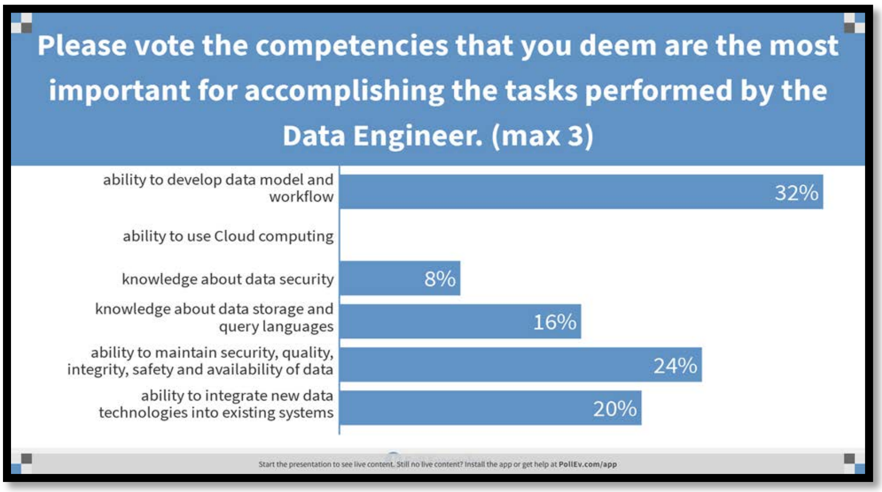

Figure 21 Skills of Data Engineer

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Figure 21 depicts the ability to develop data models and workflow has a high priority for pilots but the ability to use cloud computing does not have importance in this job position for them.

5.1.2.5 Visual Data Designer

Figure 22 shows the opinions of participants in BOOST4.0 (G.A. meeting – July 2019 – Lisbon) related to skills of "**Visual Data Designer**":

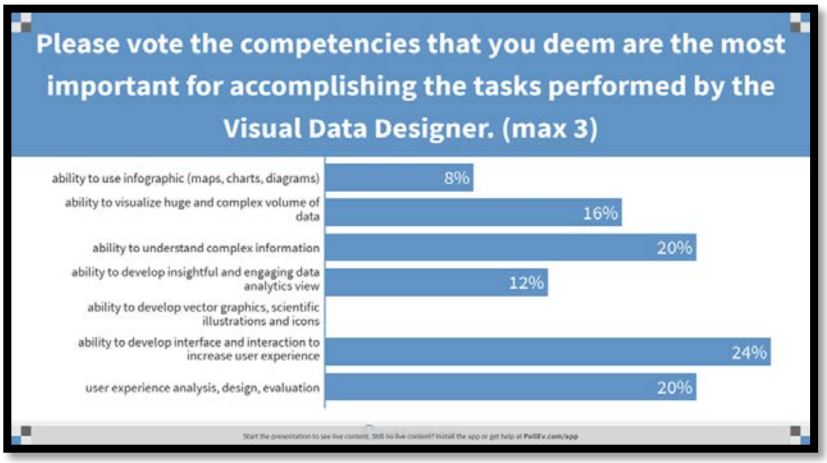

Figure 22 Skills of Visual Data Designer

Figure 22 indicates the ability to develop interface and interaction to increase user experience has high priority and the ability to create infographics has low priority for pilots. Besides, the ability to develop vector graphics, scientific illustrations, and icons does not have importance in this job position for them.

It should be noted that the analysis and prioritization done in this section can be extended to the DT-ICT-07-2018 and SHOP4CF projects.

5.2 Skills needs and adoption plans in Data Spaces Industrial Cases (BOOST4.0)

In order to validate the **People, dimension** for Pilots and Replication Factories in projects, a questionnaire was designed in the form of a table (Table 2) in relation to the aforementioned job profiles which the pilots can complete according to their situations.

The analysis and methodology which has been done in this section is related to BOOST4.0 project and can be extended to the DT-ICT-07-2018 and SHOP4CF projects.

In the first column of this table, all the jobs related to "**Data science management**" and the skills required for them were mentioned, and in the second and third columns, pilots indicate whether they **needed** these skills in their company or were **currently using them**. To display this information, a numerical range between **1 and 5** has been used, which 1 depicts "**basic level required**" and 5 shows "**expert level required**".

In the last column of this table, the pilots specify if the skills are possessed by the company itself or by the BOOST4.0 partners' collaboration. In addition, they specify how the skills gaps evidenced have been filled: "by training courses", "up-re-skilling", "hiring new personnel", "opening new collaborations" ….

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Table 2 Big data roles and competencies questionnaire – Example

Boost 4.0 BIG DATA FOR FACTORIES — FILL YOUR FUTURE

Pease indicate with YES/NO if a job profile is needed in your pilot. if YES, rank from 1 to 5 the skills reported for that specific profile
(1 = basic level required in the pilot, 5 = expert)

Pleas specify if the skills are possessed by the cpmpany itself or by the BOOST partners copllaborating in the pilot.

Pleas also specify how the skills gaps evidenced have been filled by training courses up- re-skilling, by hiring new personnel , by opening new collaborations

Job Profiles and related skills	Needed (M36)	Possessed (M36)	Comments
Data Science Architect			
ability to integrate data universe			
knowledge about big data architectural standards			
knowledge and ability to select software platforms for big data (Hadoop, Data Lake)			
knowledge about hardware platforms for big data (performances, costs, scalability, flexibility			
Data Science Manager			
knowledge about domain-specific processes			
knowledge about business processes			
knowledge about performances indicators			
communication with domain experts			
Data Scientist			
knowledge about programming language (R, Python)			
ability to identify and interpret relevant data sources			
knowledge about advanced mathematical and statistical models			
knowledge and use of machine learning			
knowledge and use of Bayes classifier			
knowledge and use of Deep Learning techniques			
knowledge and use of Operational Research methods			
knowledge and use of optimization algorithms			

The analysis performed on industrial cases in the BOOST4.0 project shows that, since SMEs need different levels of Data Science skills' job profiles (from basic to professional level) depending on the type of business; There are various solutions to cover them. Based on the analysis of the surveys that are created in this purpose and filled out by pilots and replications. The most important solutions in "**Data Science Architect**" field can be **involving other company departments** and **cooperation with project partners**. Figure 23 depicts an example of the analysis for " Data Science Architect" in Prima and PLC which are pilots in BOOST4.0 project.

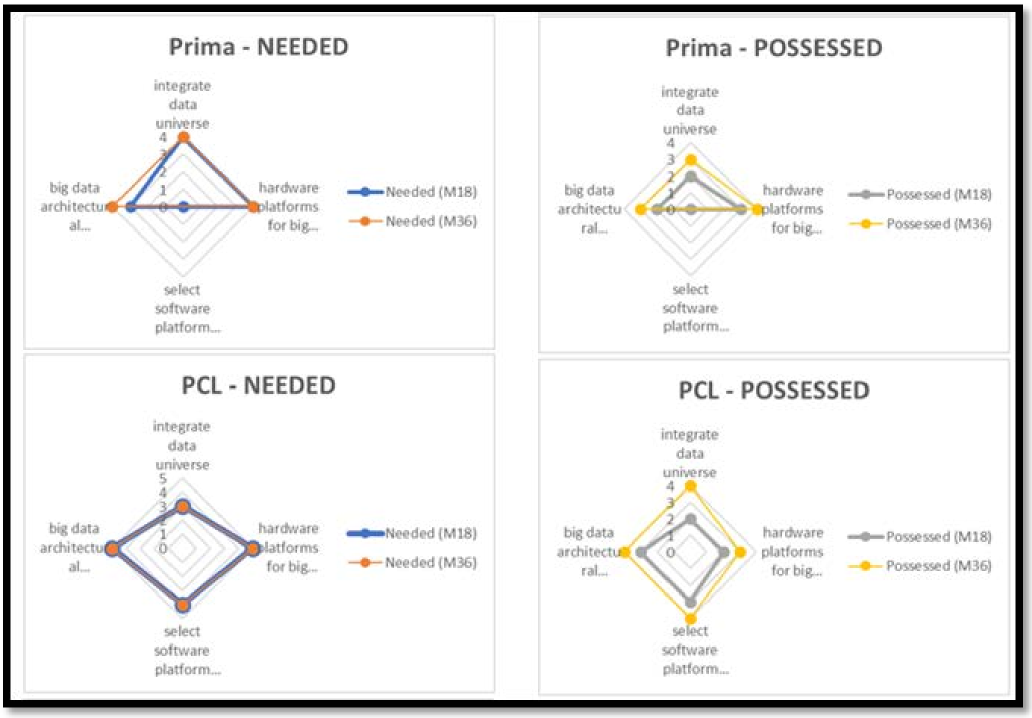

Figure 23 Example of the analysis for " Data Science Architect"

In " **Data Science Manager**" and "**Data Scientist**" job profiles, efficient solutions can be **holding training courses**, **cooperation with project partners**, **investing in actual data science sections** and **using further of company's resources**. Figure 24 depicts an example of the analysis for " **Data Scientist** " in Prima and PLC which are pilots in BOOST4.0 project.

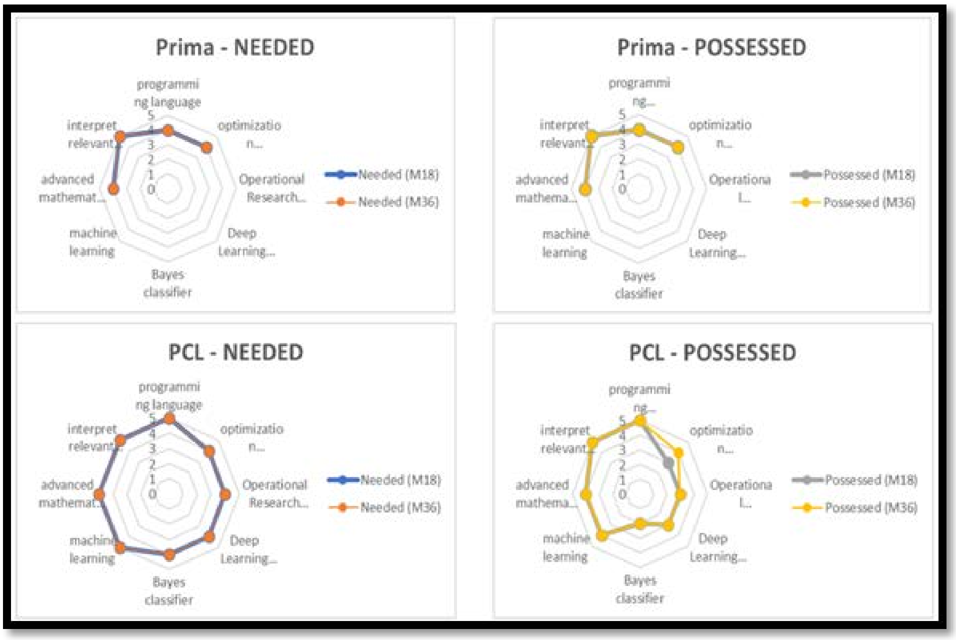

Figure 24 Example of the analysis for " Data Scientist "

And finally, in "**Data Engineer**" and "**Visual Data Designer**" job profiles, these solutions can **be cooperation with project partners**, **holding training courses**. Figure 25 depicts an example of analysis for " **Visual Data Designer** " in Prima and PLC which are pilots in BOOST4.0 project.

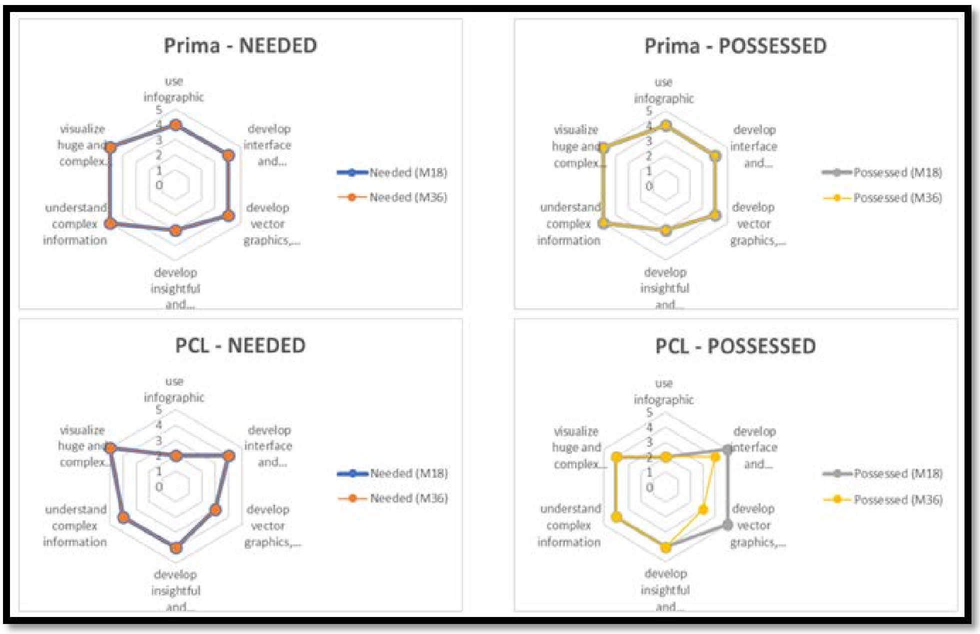

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Figure 25 Example of the analysis for " Visual Data Designer "

Further validation of the whole Data Science skills analysis and development method (online survey) will be performed on DT-ICT-07-2018 Innovation Actions in second half 2021, as soon as they have achieved a consistent maturity of their Industrial Pilots. Further validations are foreseen in 2022 inside the DT-ICT-07_2019 DMP innovation actions (SHOP4CF in particular) and I4MS Phase IV projects: they will be reported in the next edition of this deliverable D4.3 at M30.

5.3 Roles and Professions for Circular Economy pathway

This chapter will reflect on needs for new professions and skills related to digitally enabled development of circular (and sustainable) manufacturing industry. Thus, most of the roles and professions in Industry 4.0 - and especially new professions and skills identified related to data spaces pathway (5.2.) are relevant also here. Therefore, this section will focus on roles and professions for Circular Economy.

5.3.1 The variety of roles and Professions and their skills

There is a broad variety of different Circular manufacturing strategies of companies (see Table 2) and the novel roles and profession may emerge based on these strategies. The roles and emerging professions may vary as well as skills needed for tasks. Typically, the emerging professions require multidisciplinary skill sets integrating both business and technology aspects.

Table 3: Circular Manufacturing strategies and novel professions (adapted and complemented from Acerbi and Taisch, 2020b)

Strategy	Shot description	Novel roles and professions
Reuse	This strategy, once analyzed the product status and condition, aims to plan and perform all the activities and processes enabling to reuse the product directly at the end of its life cycle	Person(s) for inspection and classification of incoming used products, and plan the
Remanufacturing	This strategy aims to plan and perform all the activities and processes required to restore a used product in compliance with its original quality, specifications, performances, and warranty	Product lifecycle manager to takes an very broader view to closing supply chain gaps. It can involve creating new types of products and ways to make them, as well as finding new sourcing avenues and channels of distribution. Provides within the organisation training to understand, evaluate and promote the environmental attributes of its offerings. Skills needed include also life cycle assessment tools.
Recycling	This strategy, through chemical and physical transformation processes, aims to reuse the components or materials by reducing resources consumption and pollution generation	
Disassembly	This strategy aims to define and perform all the activities and processes to disassemble in sub-components and materials the product and, under CE perspective, this strategy enables to easily recycle or reuse the single parts	
Circular Design	This strategy aims to plan and perform all the activities to be done at the design phase of the product life cycle in order to prevent excessive resource	Product designer to radically reinvent the design in order to prevent excessive resource consumption and keep carbon out of the atmosphere.

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	consumption. This strategy eases end-of-life circular practices such as disassembly and thus, recycling, reuse and remanufacturing	
Cleaner Production	This strategy, being based on product optimization, input substitution and sharing of renewable and recyclable resources, enables to limit resources consumption and toxic substances used in the production processes	Specialist to evaluate environmental impacts of production technologies
Material Efficiency (Reduce)	This strategy aims to plan and perform all the activities and processes to optimize material used along the production process and product usage	In addition to product designer, the collaboration between the material and production specialists have an important role in this strategy.
Waste Management	This strategy corresponds to all the activities and processes required to dismantle waste generated by manufacturers by also handling hazardous waste)	Service providers specialized to waste management, have specialists that know obligatory responsibilities as well as are enable to boost circularity possibilities of waste flows
Servitization (Product-Service system)	This strategy aims to plan and perform all the activities and processes to sell a service by using a product as a means. It uses both tangibles (products) and intangibles (services) to satisfy final customers' needs by limiting resources consumption.	Customer service persons, beyond purchasing, to help customers choose resource-efficient options, Platform operators enabling the follow-up of resource
Closed-loop supply chain/ Reverse Logistics	This strategy aims to plan and perform all the activities to establish reverse flows of resources along the supply chain.	Network sustainability or reverse logistics manager to coordinate reuse, repurpose or share industrial machines and products
Industrial Symbiosis/Industrial Eco-Parks	This strategy refers to the physical exchange of resources as materials, energy, and by-products among industrial actors that do not belong to the same supply chain.	Circular investment specialist to identify and match-make actors to boost physical exchange of resources as materials, energy.

As the identified circular manufacturing strategies presented at the above table showed, successful transformation into circular business requires a considerable shift in cross-disciplinary skills, mindset and collaboration as manufacturing companies have to adapt their products and solution design, and continuously engage with their customers and ecosystem partners. Circular business models can be applied across the entire value chain – however, the biggest value potential is typically achieved during the product usage phase, requiring increased forward integration of manufacturing companies.

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5.3.2 First results of prioritisation

CE has the potential to revolutionize many industrial sectors as companies begin to develop their business models around the ideas of extending product life cycles, expanding from products to services, and focusing on renewability and resource efficiency, or closing the loop. A manufacturing company, in order to become more circular from typically quite an linear operation models of manufacturing networks, needs to first make strategic decision and consider renewal of its business model and modify its culture moving towards a sustainable attitude and understand the core of the CE principles.

According to a survey commissioned at the end of year 2020 by VTT[60], manufacturing SMEs are reluctant to invest in new technologies. Only one third of the 200 SMEs in the manufacturing industry that responded to the survey seek growth and new business by investing in technology. The survey results highlighted that as a rule, SMEs seek growth and new business from new customers, new products, and new partners and networks. Compared to previous 2018 survey, there has been a clear drop in the companies' willingness to invest in new technologies. As a positive side of the survey result, it can be stated that the SMEs have identified the importance of intangible assets, when seeking for renewal and growth. Circular economy cannot be achieved by one company alone, and therefore SMEs’ willingness to seek new collaboration partners between traditional and new actors in the ecosystem is an important step required to close the loops efficiently.

In general, the manufacturing industry has been suffering from insufficient availability of skilled labour for a long time. This already seems to be reflected in the companies’ reluctance to make investments. The result of survey emphasizes that the SMEs in the manufacturing industry seem to be lacking resources and expertise needed for long-term strategic planning.

Thus, in line with the above, the development workshops around the CE pathway (during the year 2020) and the analyses done based on the interview data of DT-ICT-07-2018 related to CE business models showed that the critical skill requirements are at the moment strategic capabilities of manufacturing industry companies. In other words, circular economy or sustainability are currently quite seldom seen as a competitive advantage of companies. In line with that insight the people dimension of 6P model, which aims at assessing the skills owned or to be owned among manufacturing SMEs’ human capital, highlight the need for change in mindset and engagement (see Table 4).

Table 4: Five levels of CE pathway and people dimension

	Level 1: Linearity	Level 2: Industrial piloting	Level 3: Material Management	Level 4: CE Thinking	Level 5: Circularity
People	Ad-hoc engagement of individuals, not comprehensive engagement	Engagement and awareness raising, systemic empowering through champions	Cultural transformation and qualified people (skills)	Circular suppliers selection and value network level indicators	Sustainable government’ requirements and European Green Deal?

5.3.3 Skills needs and adoption plans in Industrial Cases (KYKLOS and digiPRIME)

Both KYKLOS and digiPRIME projects consider the new value creation models, where data and services become products in themselves, composing new value circles through new channels, new markets and

60 https://www.vttresearch.com/en/news-and-ideas/survey-smes-reluctant-invest-new-technologies-help-available

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customers. The KYKLOS project looks at product servitisation strategy through the proposal of maintenance services, and product recycling/ reuse; and the DIGIPRIME project supports the future systematic creation of cross-sectorial circular value-chains for the remanufacturing and re-use of high added-value components.

Through cross-sector pilots, the KYKLOS project adopts a life cycle management approach to devise and enable a set of product strategies for reconfigurable and reusable products, using a set of set of intelligent tools for real time analytics and prediction, as well as recommendation systems. The DigiPrime project is focused on the development of a circular economy digital platform that enables the creation of circular business models based on the data-enhanced recovery and reuse of functions and materials.

Table 5: Circular Manufacturing strategies and the two example projects

Strategy	KYKLOS	digiPRIME
Reuse	X	X
Remanufacturing	X	
Recycling		X
Disassembly	X	X
Circular Design	X	
Cleaner Production		
Material Efficiency (Reduce)		
Waste Management		
Servitization (Product-Service system)	X	
Closed-loop supply chain/ Reverse Logistics	X	X
Industrial Symbiosis/Industrial Eco-Parks		X

The skills developed on two DT-ICT-07-2018 projects focus on technological tools, such as real time analytics and prediction, as well as recommendation systems at the KYKLOS project or circular economy digital platform developed at the digiPRIME project. Therefore, further analyses are needed in order to provide deeper understanding on identified skill needs - especially related to the intangible skill sets, i.e., strategic choices, business models as well as organisational culture.

According to a survey commissioned at the end of year 2020 by VTT, manufacturing SMEs are reluctant to invest in new technologies. Only one third of the 200 SMEs in the manufacturing industry that responded to the survey seek growth and new business by investing in technology. The survey results highlighted that as a rule, SMEs seek growth and new business from new customers, new products, and new partners and networks. Compared to previous 2018 survey, there has been a clear drop in the companies' willingness to invest in new technologies. As a positive side of the survey result, it can be stated that the SMEs have identified the importance of intangible assets, when seeking for renewal and growth.

In general, the manufacturing industry has been suffering from insufficient availability of skilled labour for a long time. This already seems to be reflected in the companies' reluctance to make investments. The result of survey emphasizes that the SMEs in the manufacturing industry seem to be lacking resources and expertise needed for long-term strategic planning and visioning for the future business opportunities.

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5.4 Roles and Professions in the CyberSecurity pathway

5.4.1 The roles, Professions, and their skills

Different roles and responsibilities need to deal with CyberSecurity within any organization. These require specific skills related to the organization's CyberSecurity risk profile, identified policies, procedures, related activities. For these a variety of skills related to the different roles being set within the organization, that can be Professions can be identified. Some roles can be outsourced, can be provided through services providers or can be insourced for specific roles or Professions, but the final responsibility of CyberSecurity management is part of the organization itself. For manufacturing companies, additional skills related to operational systems (cybersecurity for industrial control systems, data exchange platforms, supply chain and vendor management) will likely be either equally or slightly more important than the skills related to and required for CyberSecurity of companies only operating information systems and only to a lesser extent operational system (e.g., HVAC, physical access control systems, …).

The following paragraphs try to provide an answer to the question: '**which skills do you think are required for a CyberSecure Connected Factory**?". As the question itself already indicates, there is a level of uncertainty, related to the situation of the company itself, but also the continuously moving and evolving concept of the Connected Factory, therefor leaving making the requirements for its CyberSecurity fluid and evolving. As an example, a Connected Factory connecting today over a tunnelling system (VPN) over the internet to connect its headquarters to all operating factories around the globe, independently operating plants will not need to have the same CyberSecurity skills when trying to maintain that VPN themselves today, versus when - in the near future – they connect all of their equipment over 5G directly into the cloud, and the headquarters gets the same or even more in depth insights an accuracy than before.

On the basic level of any organization is the need for CyberSecurity awareness, the basic understanding of CyberSecurity challenges, capabilities of identifying a potential threat or danger and the basic skills required to avoid actions and activities that can cause CyberSecurity incidents.

In order for any CyberSecurity policy and list of related activities to be effective, CyberSecurity needs to be supported by the whole organization, as it is secure as its weakest link. While humans - individual persons - are an integral part of the CyberSecurity ecosystem made up of people, processes and technology; these humans require specific attention when it comes to skills and their evolution.

In the following overview, we aim to present a basic perspective of skills required for a number of these roles, sometimes identified as Professions and their related skills. As the complexity of CyberSecurity increases, - due to the complexity of the manufacturing organization, and its interactions with the outside world – additional roles and Professions will need to be organized, likely duplicating or splitting the three identified roles and therefor adding additional layers of complexity in the organization and adding skills related to the specific functions, and subsequent skills required.

1. CyberSecurity Management
2. Operations Management
3. Field Engineer – Operator

But equally other roles within the organization working on emerging technologies and digital transformation will require basic and more evolved CyberSecurity skills. Examples are the Digital Transformation Officer, the

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Operations Director – Operations Manager, the Plant Manager, Business Line Managers, Marketeers, Product developers and designers, the Data Scientists, …

5.4.2 Holistic perspective of required CyberSecurity Professions and related skills

From a Profession perspective and considering Roles within the organization the following pyramid perspective gives an indication of specific titles relevant for CyberSecurity. The perspective is set from the consideration of preparing for a career in CyberSecurity and does not take into account the specific requirements from a risk or security requirements perspective.

That means that not all listed functions are required in a manufacturing organisation, but the three main levels (Senior Management, Mid-Level and Entry) can be retained for, but the roles from Mid-Level down will mostly not be needed for traditional Manufacturing companies. In our Entry level we consider the skills required for the Field Engineer – Operators, rather than the CyberSecurity Professionals that might be required for the HyperConnected or CyberSecure Manufacturing companies.

In view of Connected Factories and Industry 4.0 related ongoing developments, special attention can be paid to the CyberSecurity requirements identified by so called Hybrid Threats for which the EC is developing a contractual Public-Private Partnership that aims to -build trust among different market players and develop synergies between the demand and supply side.

While accompanying measures will primarily focus on civilian cybersecurity products and services, the outcome of these initiatives should allow technology users to be better protected also against hybrid threats.[61]

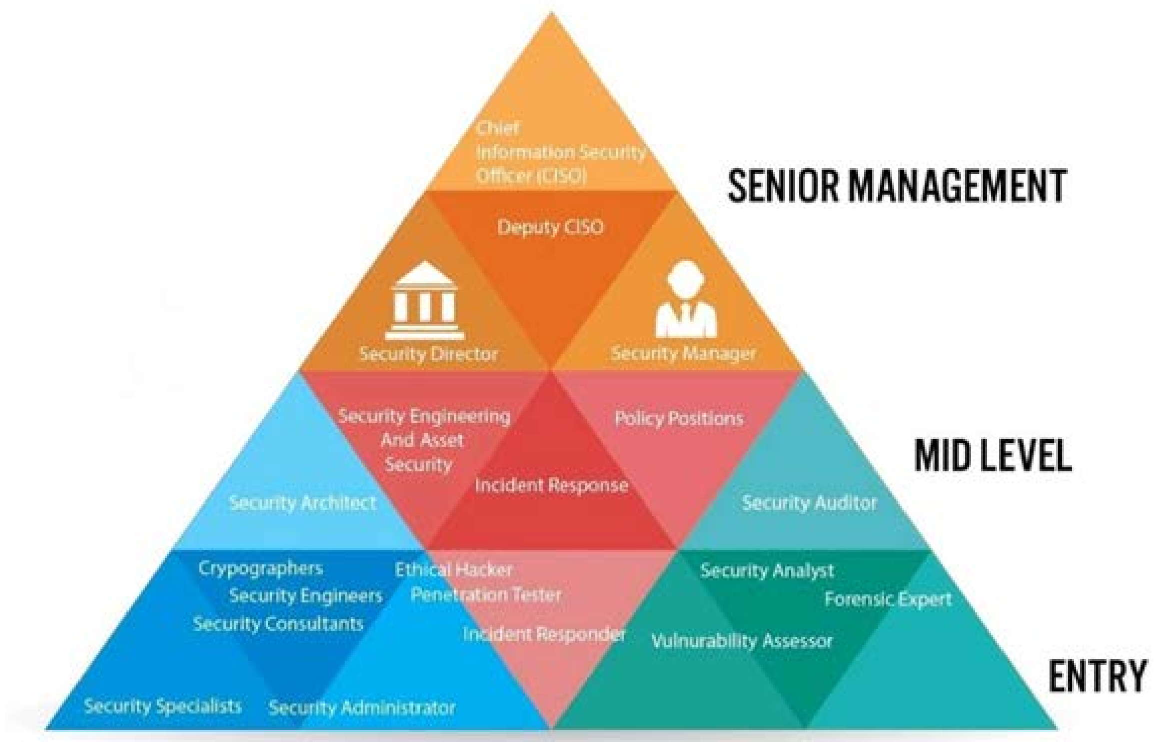

Figure 26 Pyramid of specific titles relevant for CyberSecurity

61 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016JC0018&from=EN, p11.

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5.4.3 Required Skills and descriptions

The following are a list of skills which have been made available through existing CyberSecurity skills services providers or are a collection of different skills sets capable of addressing the required skills.

Key concept is that CyberSecurity tries to secure all underlying layers of systems, technologies and components.

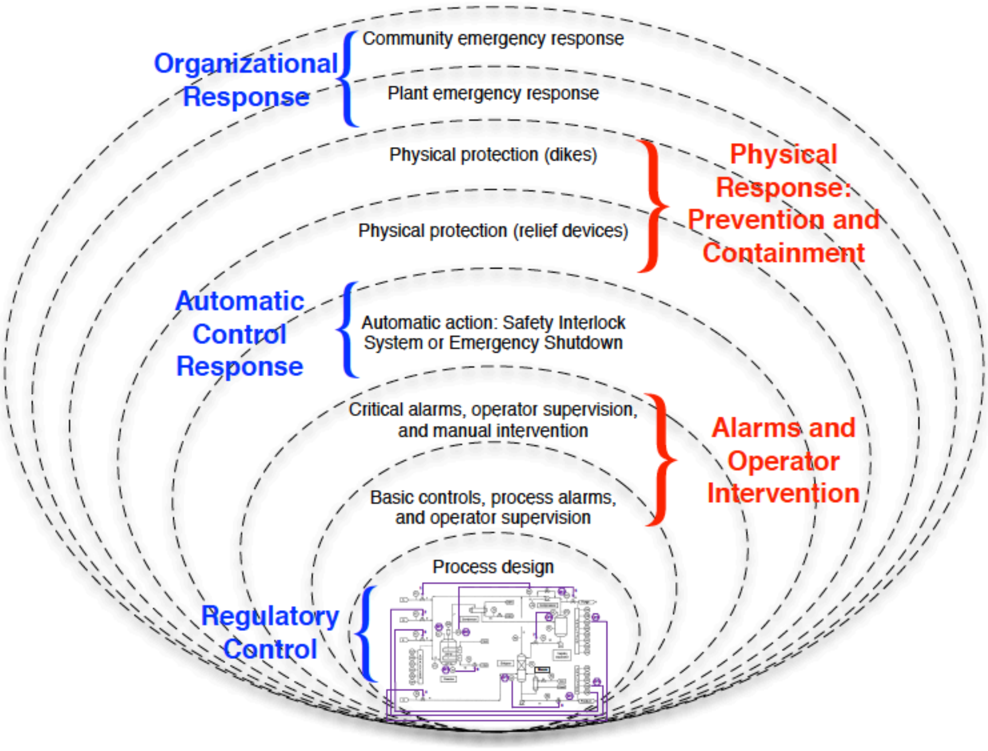

Figure 27 : Layers of protection for safety-critical ICS – which is the fundamental consideration for a risk-based approach for a Cyber Physical System, or an Operational Technology – ICS / IACS environment, the basis for the Connected Factory and the CyberSecurity Pathway.

5.4.3.1 Entry Level – from Field Engineer & Operator AND UP - CyberSecurity Skills Assessments

As many as 82% of companies utilize some type of pre-employment assessment, with as many as 54% using a form of job scenario driven simulation, for potential hires. Factories might already be lucky having some CyberSecurity skills available within their organization.

A skills assessment will help identifying which expertise is available, and what skills are in order to organize even a Virtual Cyber Security team, dispersed over different entities and departments, even globally; if overall CyberSecurity resources are scarce. Due to the nature of the cybersecurity field, designing a one-size-fits-all evaluator is simply not feasible, but a number of assessment tools can be selected from – both on Factory[62] and on individual[63] level. Instead, evaluation and assessment tools based on a widely agreed upon framework

62 https://www.surveymonkey.com/r/Z7RVFWV (a NIST cybersecurity assessment tool for manufacturing companies)
63 https://cybrscore.io/assessment/

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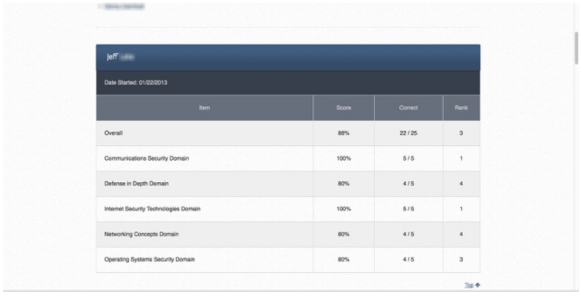
of standards that could be applied to a number of work roles and job responsibilities, would be more beneficial. For work roles that have high technical demands, such as digital investigations, incident response, secure coding, or penetration testing, it is crucial that the candidates are able to demonstrate they possess the technical knowledge and skills needed to be effective in their work-role. A hands-on practical evaluation is the best fit in this scenario.



Jeff

Date Started: 01/22/2013

Item	Score	Correct	Rank
Overall	88%	22 / 25	3
Communications Security Domain	100%	5 / 5	1
Defense in Depth Domain	80%	4 / 5	4
Internet Security Technologies Domain	100%	5 / 5	1
Networking Concepts Domain	80%	4 / 5	4
Operating Systems Security Domain	80%	4 / 5	3

Top

The Industrial CyberSecurity Center[64] (CCI) organizes specific practical workshops to assess the maturity of CyberSecurity in Industrial Organizations.

The NIST NICE Frameworks guides employers, educational organisations and government institutions in guiding throughout the skills required, and the educational components backing, on the basis of the functionalities following the NIST CyberSecurity Framework analysis. An organization that has performed their CyberSecurity Risk assessment will be able to identify its required resources and subsequent skill sets to allow to cover for the required CyberSecurity Risk management. [65] The limitation is that at the time of writing, the skill set did not include specific Industry or Connected Factory-related challenges, relating back

Description

The aim of this workshop is to provide to professionals from industrial organizations, engineering, and IT&OT integrators, the necessary knowledge to determine the cybersecurity maturity degree of an industrial organization with respect to the requirements of this organization, identifying the main security gaps, and establishing comparisons between different organizations in terms of their maturity in capacities of Industrial cybersecurity allowing the evolution of risk management to excellence levels.

All this, thanks to the Maturity Assessment tool based on C2M2.

Program

- Models of maturity
- Overview of the Tool
- Areas of strategy and organization
- Areas of assets, risks and operations
- Areas of configuration and access
- Area of continuity
- Benchmarking. 27 Relevant Objectives
- Closing of the workshop

Aimed to:

Responsible for the management of industrial cybersecurity risks, business continuity managers, information security officers, operational security officers and industrial informatics managers.

Documentation included

- Evaluation tool: Maturity of the cybersecurity process in industrial organizations.
- User Manual
- Presentations of the Workshop
- Case study

Figure 28 : example of a Maturity Assessment Workshop for an Industrial Organization, CCI - 2021

64 https://www.cci-es.org/en/programas1
65 https://www.nist.gov/itl/applied-cybersecurity/nice/nice-framework-resource-center

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to the first challenge in determining the specific risk profile from the organization or Connected or CyberSecure Factory.

Select the statements below that best describe this position's work at a high level (choose up to 3) *

- [ ] **Analyze** - Performs highly-specialized review and evaluation of incoming cybersecurity information to determine its usefulness for intelligence.
- [ ] **Collect and Operate** - Provides specialized denial and deception operations and collection of cybersecurity information that may be used to develop intelligence.
- [ ] **Investigate** - Investigates cybersecurity events or crimes related to information technology (IT) systems, networks, and digital evidence.
- [ ] **Operate and Maintain** - Provides the support, administration, and maintenance necessary to ensure effective and efficient information technology (IT) system performance and security.
- [ ] **Oversee and Govern** - Provides leadership, management, direction, or development and advocacy so the organization may effectively conduct cybersecurity work.
- [ ] **Protect and Defend** - Identifies, analyzes, and mitigates threats to internal information technology (IT) systems and/or networks.
- [ ] **Securely Provision** - Conceptualizes, designs, procures, and/or builds secure information technology (IT) systems, with responsibility for aspects of system and/or network development.

Figure 29 Questionnaire about best describe of position's work at a high level

The task list of the selected challenges required from the above listing have been detailed[66] and can be related back to a number of skills[67]. A comparison[68] was made to connect the tasks and taxonomy to the proposed European CyberSecurity Taxonomy offered by the Joint Research Centre[69].

5.4.3.2 Identification of Skills and Levels needed on the basis of existing trainings and educational programs

The following overview presents the result of a non-exhaustive analysis of available programs, educational materials to create related skills. This bottom-up approach, indicates how skills can be generated (both educated, trained, and exercised) to improve CyberSecurity for Connected Factories or CyberSecure Factories. The analysis indicates the required skills from operator (field engineer) – people working on a console, on a HMI and an operational unit; to Plant Manager – Operations Director – people managing the operations and the oversight, with view on the business, the legal considerations and requirements

66 https://niccs.cisa.gov/workforce-development/mapping-tool
67 https://niccs.cisa.gov/workforce-development/cyber-security-workforce-framework/skills
68 https://www.sparta.eu/assets/deliverables/SPARTA-D9.1-Cybersecurity-skills-framework-PU-M12.pdf
69 https://publications.jrc.ec.europa.eu/repository/bitstream/JRC118089/taxonomy-v2.pdf

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(environmental, incidents, supply chain, personnel, …); Security Management – CISO, on site or decentralized and CS Expert on site or decentralized. Green are the required skills; orange are the skills which can be complementary to the skills needed for their Profession and Roles.

Table 3 CyberSecurity Skills Connected Factories & CyberSecurity Pathways

CyberSecurity Skills Connected Factories & CyberSecurity Pathways

Skills Title	**Description**	**Example**	**Entry**	**Mid**	**Senior**	**CS Expert**
			Field Engineer, Operator	Production Manager, Operations Director	CISO - Security Manager	CS Expert, CISO Office team
Maturity Assessment	skills assessment of company and teams	NIST				
Awareness Session	demonstration of CS effects	IC4, KASP				
Basic CyberSecurity	employees who interact with computerized systems on the industrial floor. Human error, resulting from a simple lack of cybersecurity knowledge and awareness	IC4, KASP				
CyberSecurity Essentials	critical intro topics, CS-related, balanced manager and tech skills	SANS				
Digital Security in I40	CyberSecurity in I40, vulnerabilities, threat, countermeasures, use of digital manufacturing platforms, data analysis and gathering, IoT Security	ICC				
Protection of Essential Services (NIS)	industrial and information CS management, NIS, ISO 27k, IEC62443	ICC				
Base Industrial CyberSecurity	network architecture, industrial communication, network-protocol analysis, network scanning and tools, industrial cybersecurity	IC4, KASP				
ICS/SCADA Security Essentials	foundational set of standardized skills and knowledge for industrial cybersecurity professionals.	SANS				
Leading CS Change	CS culture, management, change	SANS				
Global industrial cybersecurity professional (GIAC)	GICSP training and certification - IT, engineering, CS - certification; Industrial control system components, purposes, deployments, significant drivers, and constraints	SANS				
ICS Active Defense	deconstruct ICS cyber attacks, leverage active defense	SANS				
ICS Incident Response	incident response procedures, maintain safety and reliability	SANS				

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Attack Exercise	Hands on simulation exercise, impacting the whole organization and preparing for potential incident readiness, aiming to get better organized, increase skills on management, communication, internal and external relations, recovery and resilience thinking	IC4, KASP
Industrial Cybersecurity Games	Middle-management, in Finance or Procurement divisions, for example, may not be fully aware of their roles as stakeholders in corporate cybersecurity. Simulating real-world cyber-attacks on industrial automation systems, demonstrating the main issues associated with providing industrial cybersecurity	KASP
Information Security Fundamentals	security's foundation, cyber security terminology, basics of computer networks, Security policies, Incident response, Passwords, cryptographic principles	SANS
Industrial Cybersecurity in Practice	for those with who work hands-on with industrial control systems and equipment, and for those directly responsible for IT/OT Security	KASP
diagnosis of cybersecurity in industrial automation environment	acquire accurate knowledge of state of cybersecurity of industrial facility, identification of assets, vulnerability identification, associate risks	ICC
risk assessment and management	(i) identication and, if possible, estimation of hazard; (ii) assessment of exposure and/or vulnerability; and (iii) estimation of risk	
industrial project lifecycle cybersecurity	design, business impact analysis, operations, control, improve	ICC
applying law to cyberspace and IT/OT	real-life and cyber operations do not always fit neatly within a single category, multistate regulation, intelligence, forensics	CyBOK
contract management, SLA, supply chain management	circumstances, applicable law may exceptionally impose a requirement that some contract obligations must be embodied in a specied form	CyBOK
data protection - gdpr	includes numerous obligations related to data security. This section will focus primarily on issues that recur in a security-related context.	CyBOK
creating policies that reflect system security objectives	Responsible for the cybersecurity of a program, organization, system, or enclave	NIST
application of CyberSecurity Management System	implement ICSM following SGCI and ISO27k ISMS and IEC62443 guidance,	NIST
Responsibilities in IACS	CS management, risk analysis, IEC62443	ICC

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Human factors	Psychology: the security mechanism must be 'psychologically acceptable' to the humans; Human Factors and Economics: each individual user, and the organisation as a whole; Crime Science and Economics: the effort required to beat a security measure should exceed the resources and potential rewards for the attacker	CyBOK
Cloud Security	CCSK training and certification - cloud basics, cloud security, cloud security management, identity, key management, data connectivity	CSA
Essentials for Critical Infrastructure Protection - Essential Services	specific regulations such as NIS, CIP and NERC-related	SANS
ICS Active Defense and Incident Response	deconstruct industrial control system cyber attacks, leverage an active defense to identify and counter threats	SANS
Response and Industrial Defense (GIAC)	GRID - training and certification, prove that they can perform active defense strategies specific to and appropriate for an Industrial Control System (ICS) network and systems.	SANS
ICS Cybersecurity In-Depth	exercises that demonstrate how an adversary can attack a poorly architected ICS and how defenders can secure and manage the environment	KASP
Cryptography	methodology of 'Provable Security' to dene and understand the security of cryptographic constructions. The basic design procedure is to dene the syntax for a cryptographic scheme	CyBOK
Operating Systems and Virtualization	principles, primitives and practices for ensuring security at the operating system and hypervisor levels	CyBOK
Operating System Hardening	primitives and practices for ensuring security at the operating system and hypervisor levels	CyBOK
Authentication, Authorisation & Accountability (AAA)	concepts used when implementing access control	CyBOK
Software Security	structured overview of known categories of software implementation vulnerabilities, and of techniques that can be used to prevent or detect such vulnerabilities, or to mitigate their exploitation.	CyBOK

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Cyber-Physical Systems Security	unify the common research problems related to the application of embedded computer and communication technologies for the automation of physical systems, including aerospace, automotive, chemical production, civil infrastructure, energy, healthcare, manufacturing, ...	CyBOK
conducting vulnerability scans and recognizing vulnerabilities in security systems	Performs assessments of systems and networks within the network environment or enclave and identifies where those systems/networks deviate from acceptable configurations, enclave policy, or local policy.	NIST
analyzing network traffic capacity and performance characteristics	Plans, implements, and operates network services/systems, to include hardware and virtual environments	NIST
ICS Digital Forensics for Professionals	digital forensics skills, Tools and technologies developed for IT environments are often inappropriate or simply useless, evidence collection howto, regaining control, hands-on skills	KASP, ICC
Capture the Flag in ICS	competition for cybersecurity experts organized in the form of a game	KASP
Essentials for NERC Critical Infrastructure Protection	what and the how of the version 5/6/7 standards. The course addresses the role of the Federal Energy Regulatory Commission (FERC), North American Electric Reliability Corporation (NERC), identifying BES cyber-systems	SANS
Critical Infrastructure Protection (GIAC)	GCIP training and certification - BES cyber system identification and strategies for lowering their impact rating - Nuances of NERC defined terms and CIP standards applicability	SANS

5.4.3.3 Entry Level – from Field Engineer – Operator and up – Awareness Sessions

During awareness sessions the results of some installations and designs that could have been better designed will be demonstrated. Wrong network architecture applied hardware not appropriate for open network environments such as TCP/IP, limited experiences on the industrial workplace, ... Demonstrations will show step by step the consequences and risks and dangers following the connectivity of automation networks to the internet. The intention is not to limit participants, but to showcase potential dangers and points of attention, with indications to further solutions. With a focus on practical illustrations of risks and solutions in terms of security of the automation network. From theory into practices, making it tangible for all practitioners, including field operators without any knowledge of CyberSecurity.

Awareness sessions provide employees with basic skills in understanding why CyberSecurity can be important for an organization, how it can impact on the operations, people, relations, the ecosystem and the environment in which it operates and how a small inappropriate action such as opening up internet access on a workstation on the factory floor could cause major havoc and impact the entire production. These sessions need to be rehearsed frequently in order to keep the skills of acknowledging, but also being able to identify, detect and respond properly to the actions.

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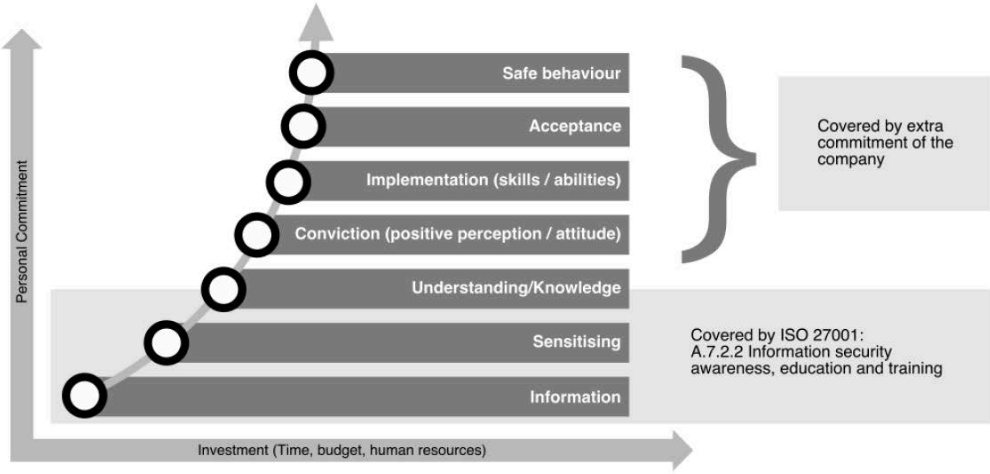

Figure 30 Security Awareness is continuous Work In Progress and needs to lead to Behaviour[70]

Figure 31 awareness example increasing CS skill sets on the factory floor, example by Kaspersky[71]

70 https://www.cybok.org/
71 https://ics.kaspersky.com/trainings-and-awareness/

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5.4.3.4 Entry Level – from Field Engineer – Operator and up - Cyber Security Essentials

Introduction to Cyber Security training course jump-starts security knowledge by receiving insight and instructions on critical introductory topics that are fundamental to cyber security. For those who have very little knowledge of computers & technology with no prior knowledge of cyber security. A balanced mix of technical and managerial issues makes this course appealing to attendees who need to understand the salient facets of information security basics and the basics of risk management.

CyberSecurity Essentials provides a foundational set of standardized skills and knowledge for industrial cybersecurity professionals. The course is designed to ensure that the workforce involved in supporting and defending industrial control systems is trained to keep the operational environment safe, secure, and resilient against current and emerging cyber threats.

The CCI organizes a Multidisciplinary Course on Digital Security in Industry (4.0) and Protection of Essential Services.

Description

This course will take participants through the study of the State of the art of the protection of Essential services and the Digital security in the industry [4.0], both in Legislation and regulations are referred to as standards, Initiatives, management frameworks and applicable technologies, thus achieving a global vision of security management in this type of organizations. This knowledge will allow the participant, at the end of the day, to clearly establish the next steps to ensure proper supervision, management and implementation of the measures of an appropriate protection.

Program

Concepts and state of the art
- Welcome, individual presentations...
- Introduction. Terms and general concepts
- State of international art
- Relationship between protection of essential services and Security In industry 4.0
- Malware in industrial environments [4.0]
- An approach to Industrial Control systems [4.0]
- Practice: Identification of Industrial Control systems
- System Vulnerabilities and threats of Industrial Control
- Practice : Analysis of a case study (Identification of vulnerabilities, countermeasures...)
- Current situation of Industrial cybersecurity

Diagnostics, standards and recommendations
- Organizational and management aspects
- Diagnosis of Industrial cybersecurity
- Practice : Discussion on the diagnosis Applicable standards
- Recommendations and Next steps: Establishing a cybersecurity program
- Practice : Case study, development and presentation by teams of the security Plan

Practical Workshop
- Practical Workshop Presentation: HOL (Hands On Lab)
- Workshop and practical activities
- Conclusions

Aimed to:

This course is aimed primarily at those responsible for managing cybersecurity risks in industrial organizations, as well as consultants and auditors of risk management systems. Also aimed at industrial automation professionals who need to understand how to manage the OT risks.

Documentation included

- **Guide for the implementation of an industrial cybersecurity management system**
- **Good practices for the diagnosis of cybersecurity in industrial environments**
- **Good practices in the forensic analysis of automation systems and Industrial Control**
- **Maturity Assessment Tool**
- **Course Presentations**

Figure 32 : example of program of Multidisciplinary Course on Digital Security in I4.0 and Protection of Essential Services

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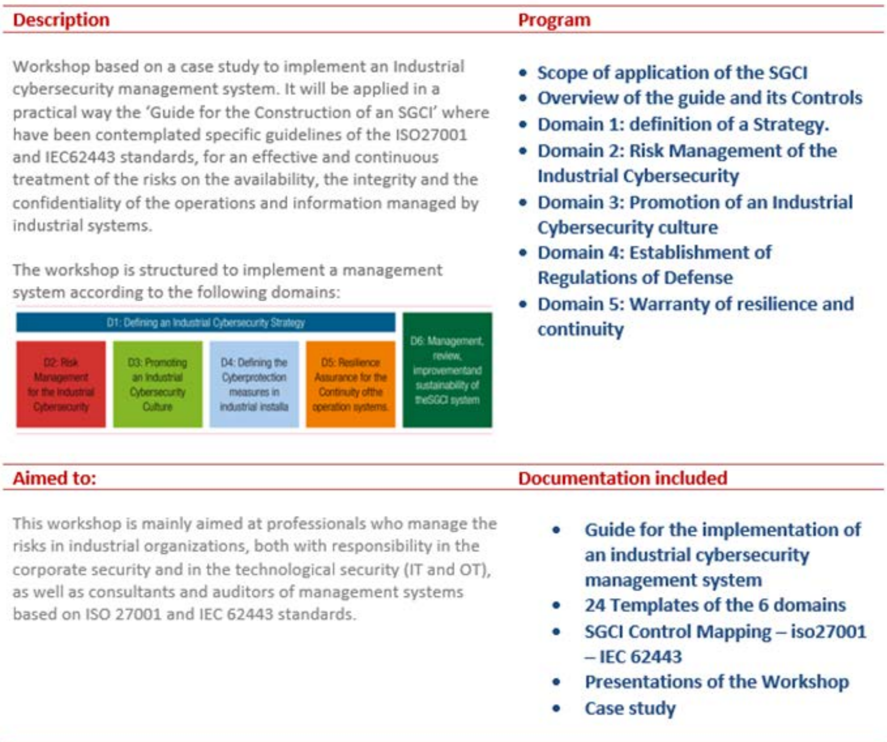
5.4.3.5 Mid-Level – from Production Management – Factory Directory and up - CyberSecurity Management

Leading Cybersecurity Change: Building a Security-Based Culture, learns how to build, manage, and measure a strong security culture by leveraging the latest in organizational change and real-world lessons learned.

The Global Industrial Cyber Security Professional (GICSP) bridges together IT, engineering and cyber security to achieve security for industrial control systems from design through retirement. It contains topics such as Industrial control system components, purposes, deployments, significant drivers, and constraints; Control system defense, attack surfaces, methods, and tools; Incident-response skills in a control system environment, governance models and resources. Course are designed to ensure that the workforce involved in supporting and defending industrial control systems is trained to keep the operational environment safe, secure, and resilient against current and emerging cyber threats.

ICS Active Defense and Incident Response will help you deconstruct industrial control system cyber attacks, leverage an active defense to identify and counter threats in your ICS, and use incident response procedures to maintain the safety and reliability of operations.

An in-classroom lab setup that move students through a variety of exercises that demonstrate how an adversary can attack a poorly architected ICS and how defenders can secure and manage the environment. Representative of a real ICS environment, the classroom setup includes a connection to the enterprise, allowing for data transfer (i.e., Historian), remote access, and other typical corporate functions. The CCI organizes workshops on Application of Industrial CyberSecurity Management System.



Description	Program
Workshop based on a case study to implement an Industrial cybersecurity management system. It will be applied in a practical way the 'Guide for the Construction of an SGCI' where have been contemplated specific guidelines of the ISO27001 and IEC62443 standards, for an effective and continuous treatment of the risks on the availability, the integrity and the confidentiality of the operations and information managed by industrial systems. The workshop is structured to implement a management system according to the following domains:	• Scope of application of the SGCI • Overview of the guide and its Controls • Domain 1: definition of a Strategy. • Domain 2: Risk Management of the Industrial Cybersecurity • Domain 3: Promotion of an Industrial Cybersecurity culture • Domain 4: Establishment of Regulations of Defense • Domain 5: Warranty of resilience and continuity

Aimed to:	Documentation included
This workshop is mainly aimed at professionals who manage the risks in industrial organizations, both with responsibility in the corporate security and in the technological security (IT and OT), as well as consultants and auditors of management systems based on ISO 27001 and IEC 62443 standards.	• Guide for the implementation of an industrial cybersecurity management system • 24 Templates of the 6 domains • SGCI Control Mapping – iso27001 – IEC 62443 • Presentations of the Workshop • Case study

Figure 33 : example of a program on Industrial CyberSecurity Management including the setup of an ISMS for industrial environment (ICMS) following IEC62443 and ISO27k, by CCI - 2021

5.4.3.6 Senior Level – from CyberSecurity Management – CISO office and up - CyberSecurity Experts

The Senior Level can be split as CyberSecurity Management, including the CISO office and the CyberSecurity Experts required for further deep diving expertise in CyberSecurity for Industrial Control Systems, Vulnerability assessments, pentesting, …

Leading Cybersecurity Change: Building a Security-Based Culture, learns how to build, manage, and measure a strong sEssentials for NERC Critical Infrastructure Protection course empowers students with knowledge of the what and the how of the version 5/6/7 standards. The course addresses the role of the Federal Energy Regulatory Commission (FERC), North American Electric Reliability Corporation (NERC), and Regional Entities, provides multiple approaches for identifying and categorizing BES Cyber Systems, and helps asset owners determine the requirements applicable to specific implementations.

Offensive ICS Training can be a two-day course to allow execution of technical security audits within industrial environments. The focus is a hands-on experience for the CyberSecurity teams with introductions to PLC programming and industrial control systems, industrial communications, scanning ICS networks, industrial networks & system enumeration. During the hands-on part there will be examples on reversing proprietary industrial protocols, exploiting industrial control system and the industrial CTF.

5.4.4 CyberSecurity Pathways Skills Improvement

There are multiple CyberSecurity educational mechanisms, however only few are dedicated to operational systems CyberSecurity, even fewer to the combination of operational and information systems security, and finally almost none to very scarce for CyberSecurity for manufacturing and factories. Only specifically organized courses or seminars will be focusing on Connected Factories CyberSecurity. For an overview of different CyberSecurity BA and Master options, ENISA created the CyberSecurity Higher Education Database[72], collecting 124 Programmes across 24 Countries.

The ICC provides a Master Class (but only in Spanish for now) on Industrial CyberSecurity, allowing CyberSecurity experts to further engage in the domain of Industrial CyberSecurity and further train towards newly required challenges related to Connected Factories and CyberSecurity Pathways. A certification scheme is linked to the program, with three different classes white - green – black.[73] SANS is offering a continuous further improvement program on Industrial CyberSecurity, including trainings towards the GIAC – the Global Industrial Automation Certification schemes GISCP, GRID and GCIP[74].

Figure 34 the Global Industrial Automation Certification schemes GISCP, GRID and GCIP

72 https://www.enisa.europa.eu/topics/cybersecurity-education/education-map
73 https://www.cci-es.org/web/cci/detalle-actividad/-/journal_content/56/10694/316158
74 https://www.giac.org/certifications/industrial-control-systems

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Other mechanism can include:

- Cyber Ranges: online and onsite training simulation environments, simulating a real-life situation with industrial activities and incidents.
- Periodical courses classroom or e-learning
- Toolboxmeetings
- News letters - briefings
- Cybersecurity awareness flyers
- Oneliners - Quotes
- Narrowcasting- Webcasts
- Incident Exercises, Serious gaming & Quizzes
- Simulation Table Top, Cyber Ranges (system platforms)
- Sharing experiences of incidents and incident handling

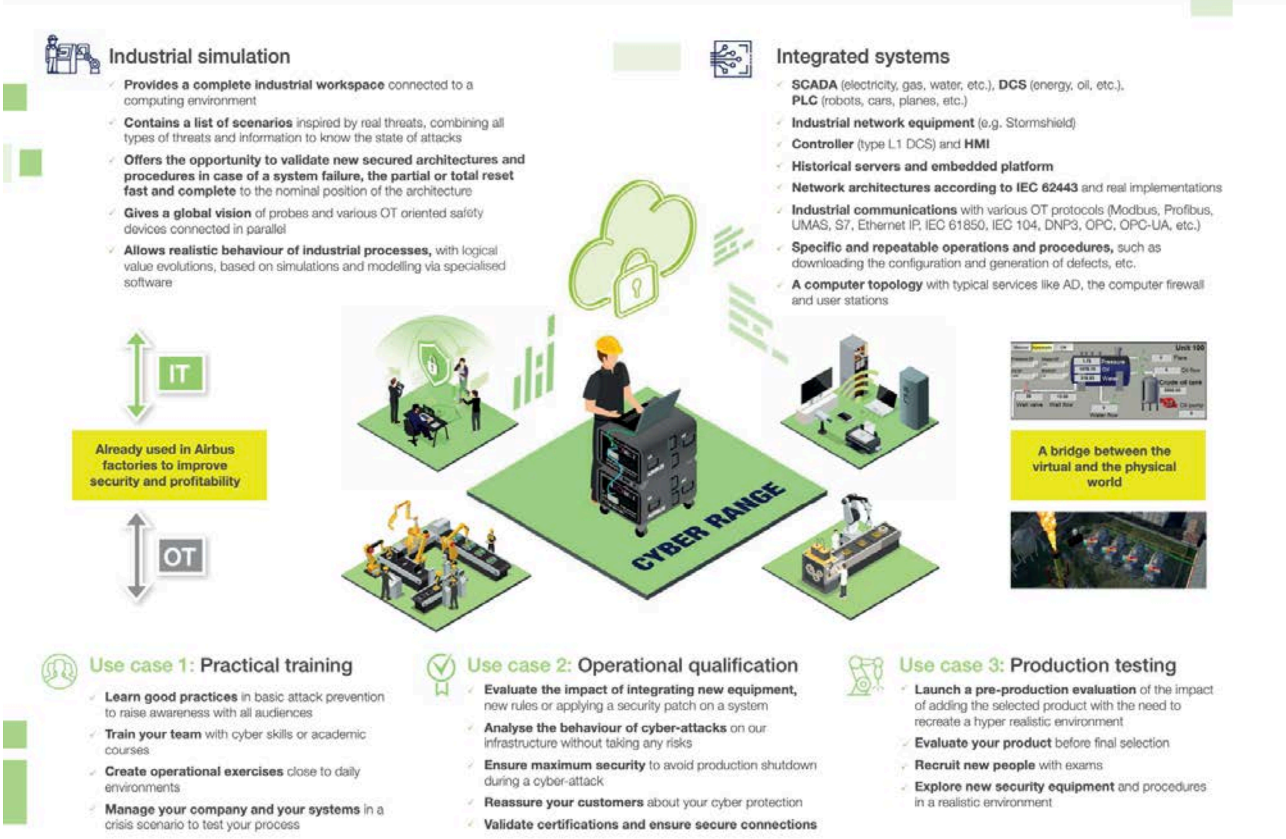

Figure 35 example of a Cyber Range for OT by Airbus Cyber Security[75] as being improved by the SECOIIA[76] project

75 https://airbus-cyber-security.com/wp-content/uploads/2020/01/Brochure-CyberRange-OT.pdf
76 https://secoiia.eu/

6 Conclusions and Future Outlook

The result of this deliverable is related to the list of emerging new skills and job requirements and, eventually, a prioritization for critical ones, in terms of need and availability, regarding the transition towards a digitalized manufacturing sector.

In this Regard, after reviewing previous studies conducted in the field of Digital transformation, Market developments, Technological trend, introducing the 6Ps People dimension model (aimed at supporting manufacturing companies in defining it current level of digital maturity) and jobs related to data science management such as data science manager, data scientist, data science architect, data engineer and visual data designer. The methodology (questionnaires) for prioritizing each of the skills according to pilots' conditions, pilots' current status, requirements for the future, and approaches to be adopted were introduced.

In the Circular Economy pathway section, VTT also after introducing a wide variety of different Circular manufacturing strategies of companies such as reuse, remanufacturing, recycling, etc. and the novel roles and profession may emerge based on these strategies, discussed about result of questionnaire which is implemented in some industrial case studies (KYKLOS and digiPRIME) to understand the importance of circular economy in SMEs.

In the CyberSecurity pathway section also LSEC, by providing information about roles, professions, and requirements related to the Cybersecurity field, tried to provide an appropriate answer for this question "which skills do you think are required for a CyberSecure Connected Factory?". Besides, based on the overview provided by LSEC, due to the increasing complexity of CyberSecurity, additional roles and Professions will need to be organized, likely duplicating or splitting the three identified roles and therefore adding additional layers of complexity in the organization and adding skills related to the specific functions, and subsequent skills required.

- Cybersecurity Management
- Operations Management
- Field Engineer – Operator

In addition, based on this overview from a Profession perspective and considering roles within the organization which is set from the consideration of preparing for a career in CyberSecurity, the three main levels (Senior Management, Mid-Level, and Entry) can be retained. In this regard, LSEC after Identification of Skills and Levels needed on the basis of existing training and educational programs (Table 3), mentioned about Awareness Sessions, Cyber Security Essentials, CyberSecurity Management, and CyberSecurity Experts levels.

As a general conclusion, we can affirm that the purpose for this task in relation to preparing the list of emerging new skills and job requirements and eventually a prioritization for critical ones is well covered in this deliverable.

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