TOWARDS INDUSTRY 5.0

challenges, good practices and lessons learned from industry 4.0

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Towards Industry 5.0 – challenges, good practices and lessons learned from Industry 4.0 – compendium

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Introduction

Manufacturing is a key employment and value driving industry in the European Union. It is responsible for more than 3/4 of Europe's exports and generates more than 15% of the EU GDP. Manufacturing provides about 20% of all jobs in Europe (more than 30 million) and generates a turnover of about EUR 7,000 billion in 25 industrial sectors and over 2 million companies, dominated by SMEs. European manufacturing business models are gradually shifting from cost-based approaches to high value-added competitive advantages. Emerging digital technologies combined with new forms of labour organisation have given rise to smart factories, characterised by innovative human-machine communication and design. This new paradigm known as Industry 4.0/5.0 that recombines technologies with labour is changing the way SMEs design, produce, commercialise and generate value from products and related services. Advances in technologies such as the Internet of Things (IoT), 5G, cloud computing, data analytics and robotics are transforming products, processes and business models, and ultimately reshuffling global value chains in all sectors. In this regard, Industry 4.0/5.0 is the latest stage in the evolution of global manufacturing where digital technologies are being used to respond to changes in consumer demand driven by a permanently connected society. Changing business paradigms and technologies represents a historic challenge for European manufacturing SMEs as they need to undergo innovation-driven transformations towards more competitive, sustainable and modern production and business models.

Industry 5.0 is a concept introduced by the European Commission in order to address the need for a new industrial paradigm, beyond Industry 4.0, which has become more and more necessary over the years in relation to increasingly complex and pressing economic and societal challenges, such as: climate change and the collapse of biodiversity; resource scarcity; global shocks such as the COVID-19 pandemic. Industry 5.0 tries to provide such an answer and "provides a vision of the industry that aims beyond efficiency and productivity as the sole goals and reinforces the role and the contribution of industry to society" (European Commission). It complements the existing Industry 4.0 approach by specifically putting research and innovation at the service of the transition to a sustainable, human-centric, and resilient European industry. We believe that this project has brought to the target groups a wider overview on the necessity to implement Industry 4.0/5.0 in their companies in the nearest future. We paid attention to different aspects of the implementation of Industry 4.0/5.0 – not only technological ones, but also those relating to competences, which were at the core of the project.

The participating organisations have the experience in the area of Industry 4.0 and they would like to extend their knowledge and skills in the area of Industry 5.0 to different target groups. The leader of the project is ready to transfer the principles of Industry 5.0 to companies as the association has the experience in this topic. Partners from Estonia and in Italy are educational institutions which offer many training courses in this area. Additionally, the Estonian partner also provides students with education about the transformation towards Industry 4.0/5.0.

The target groups are companies and other individual people that would like to broaden their knowledge about and awareness of the Industry 4.0/5.0 concept. They must be prepared for changes. The quicker they understand that Industry 4.0/5.0 is indispensable to gaining competitive advantage, the better. The exchange of best practices from different companies will show them how to be prepared for future changes. This is especially important, given what the statistics from the partners' countries show: In Poland, in 2020, only 27% of companies invested in transformation towards Industry 4.0; 18% of them did not do this, and the rest stated that it is hard to say whether they did or will do this. As Siemens points out in its report "Digi Index 2021", manufacturing companies in Poland urgently need changes in digitalisation. Currently, only 6% of them have reached a high

level of digitalisation, and two thirds do not know whether they will spend money on this type of investment project this year. The percentage of companies declaring their willingness to invest in new technological solutions has increased by one percentage point (from 27% in 2020 to 28% in 2021).

With the launch of the National Industry 4.0 Plan in 2017, the fourth industrial revolution was sweeping across Italy. Manufacturers were investing both in hardware and software to bring about smart factories. These investments focused on predictive maintenance as well as asset and energy management. Investments in Industry 4.0 technologies were expected to increase in the years following the launch of the plan, as the Italian government promoted the digital transformation of the manufacturing sector with various fiscal advantages. In 2021, the Industry 4.0 market was expected to reach 3.1 billion euros.

Despite a tightening of limitations towards the close of 2020, Estonia's economy increased well in the early months of 2021, placing the country among the EU's fastest-growing economies. However, recent trend demonstrates difficulties in Estonian economy and in 2023 Estonian GDP declined.

CHAPTER 1. INDUSTRY 4.0 – THEORETICAL BACKGROUND

1.1. Reasons, why Industry 4.0 is important

The term "Industry 4.0" was coined in Germany as part of the "High-Tech Strategy 2020" initiative, introduced in 2011 at the Hannover Fair. It signifies the fourth industrial revolution and emphasises the integration of cyber-physical systems, the Internet of Things (IoT), and digital technologies into manufacturing processes to create "smart factories." Industry 4.0 builds on previous industrial revolutions, introducing key principles such as interoperability, information transparency, technical assistance, and decentralised decision-making. The concept gained global attention, leading to widespread initiatives worldwide to modernise manufacturing with technologies like artificial intelligence, big data, robotics, and the Industrial Internet of Things (IIoT). The ongoing evolution of Industry 4.0 involves addressing challenges such as cybersecurity, workforce adaptation, and standardisation issues, while advancements in edge computing, 5G, and analytics continue to shape the journey toward intelligent, connected manufacturing systems.

Industry 4.0, characterised by the integration of digital technologies, automation, data exchange, and smart systems in manufacturing, is crucial in the contemporary landscape. It enhances operational efficiency, facilitates predictive maintenance, and enables real-time data analytics. By fostering connectivity between machines and systems, Industry 4.0 optimises production processes, reduces downtime, and improves overall resource utilisation. The ability to collect and analyse vast amounts of data promotes informed decision-making, driving innovation and competitiveness. Additionally, Industry 4.0 plays a pivotal role in customization and flexibility, allowing companies to respond swiftly to market demands and tailor products to individual customer needs. Its impact extends beyond manufacturing, influencing supply chain management, logistics, and creating opportunities for new business models. Embracing Industry 4.0 is essential for organisations aiming to stay agile, competitive, and resilient in the rapidly evolving global business environment.

1.2. Statistics from the partner's country

1.2.1. Poland

In Poland the term Industry 4.0 is relatively stable, and well-known by the companies. However, acquisition of knowledge is not equal with the implementation of Industry 4.0 in practice.

Every year, the sectoral associations do research with companies in order to get knowledge of how advanced they are in the implementation of Industry 4.0. In 2022 it turned out that more than half of companies (52%) have encountered the term Industry 4.0. Greater familiarity with the concept was demonstrated by large manufacturers (62%) than medium-sized ones (41%). As many as 70% of companies familiar with the Industry 4.0 concept were planning, or had already begun to implement solutions that are part of it. Large companies were the leader here, as more than 3/4 of them (77%) had taken such actions. Among medium-sized players, the figure was 59%, but both groups were equally eager to declare the implementation of these technologies in the future. Manufacturers of machinery and equipment (87%) and automobiles and transportation equipment (70%) were the most enthusiastic about this process.

The European Commission is preparing the Digital Economy and Digital Society Index (DESI). In the DESI 2022 ranking, Poland is ranked only 24th from last among the 27 European Union countries. In the human capital category, Poland ranks 24th among all EU member states, and in terms of connectivity in 2021, Poland ranks 25th among EU countries. On the other hand, in terms of digital technology integration, the index data shows that Poland ranks only 24th. Poland performs best in the category of digital public services, as it ranks 22nd; in terms of open data (inside the category of digital public services), Poland significantly outperforms the other EU countries, ranking a high fourth for this indicator. In the Polish industrial sector, this looks average or even poor. Data for 2022 shows that only 2 percent of Polish industrial companies are at a very high level of use of these solutions and have between 9 and 12 points, while 10 percent have this share at a high level, i.e. between 6 and 9 points[1]

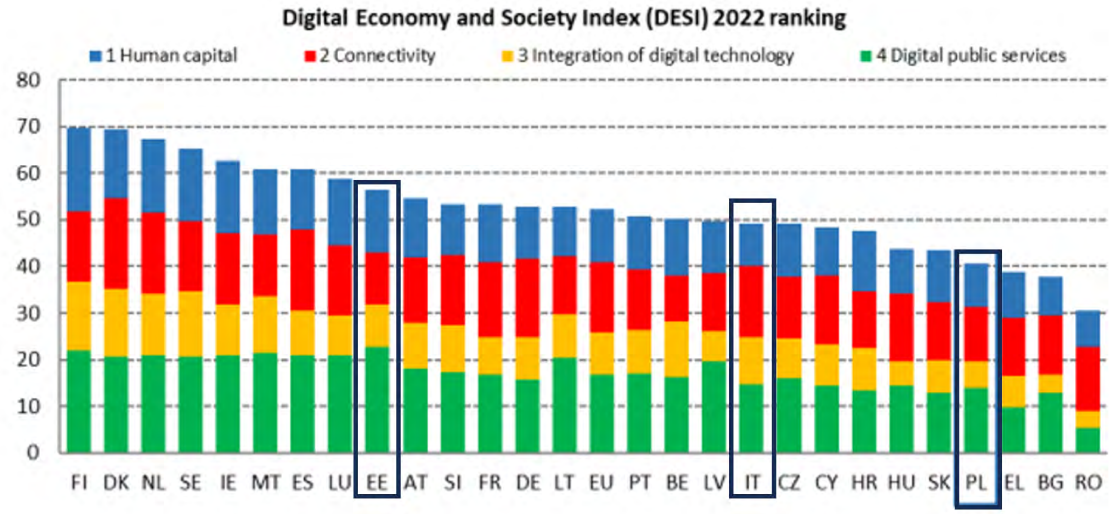

Figure 1. Digital Economy and Society Index – comparison between Poland, Italy, and Estonia.

Source: Source: DESI 2022, European Commission.

From the project partnership Poland is the least advanced in digital skills, followed by Italy, and Estonia as the most advanced.

1.2.2. Italy

Italy is one of the leading countries in the European Union in terms of its production value, and it has been actively involved in adopting Industry 4.0 technologies. The National Industry 4.0 Plan, launched in 2017, has driven manufacturers to invest in smart factories using predictive maintenance and energy management systems. The Italian government has provided incentives for companies to embrace digital transformation, leading to an expected growth in the Industry 4.0 market to 5.1 billion euros by 2026.

Internet of Things (IoT) has played a crucial role in revolutionizing industries in Italy, with companies utilizing IoT technologies to improve operational efficiency and offer new services. The adoption of IoT technologies has also extended to households, with smart metering being a key sector between 2016 and 2018.

Furthermore, the National Industry 4.0 Plan has prioritized investments in training and skills development to bridge the skills gap in the industry. Professions such as Robotic & automation managers and IoT engineers have been in high demand, highlighting the importance of upskilling in

[1] Polska w unijnym ogonie pod względem rozwoju przemysłu 4.0, https://www.wnp.pl/produkcja/polska-w-unijnym-ogonie-pod-wzgledem-rozwoju-przemyslu-4-0,758637.html

these areas. Although the Italian artificial intelligence market is still relatively small, the demand for AI experts is gradually increasing as the industry progresses.

Recent scientific research indicates that Italian manufacturing companies have limited knowledge of Industry 4.0 enabling technologies, with varying levels of adoption across different technologies. The use of Industrial Internet of Things (IIoT) and Additive Manufacturing (AM) technologies is relatively high, while Augmented Reality (AR), Virtual Reality (VR) and Artificial Intelligence (AI) are still in the early stages of adoption[2].

Interestingly, larger companies seem to have a higher adoption rate compared to SMEs, highlighting the challenges faced by smaller companies in implementing Industry 4.0 solutions. Companies with more advanced IT infrastructure tend to have a higher adoption level of Industry 4.0 enabling technologies, suggesting the importance of a mature IT system in digital technology adoption.

In terms of business functions, Production, IT, and Research and Development (R&D) departments are actively involved in Industry 4.0 adoption, while Human Resources (HR) lags behind. This may be attributed to the perceived need for aligning staff skills with digital advancements.

Moreover, companies that implement multiple Industry 4.0 technologies tend to involve more business functions, indicating a correlation between technology adoption and business function involvement. Companies are primarily driven by cost reduction in adopting Industry 4.0 technologies, while acquiring and developing adequate competencies remain major obstacles.

Overall, this study reveals a gradual increase in awareness and practical implementation of Industry 4.0 technologies among Italian manufacturing companies over a three-year period(2021-22-23). The involvement of various business functions has also increased, particularly in Quality and Logistics departments, signalling a broader adoption of Industry 4.0.

Cost reduction remains a key benefit of Industry 4.0, while companies also seek improvements in time, quality, and flexibility. The demand for skilled competencies has become more pronounced as companies strive to evaluate and implement Industry 4.0 solutions effectively in the last years.

These significant findings need to be included in a comprehensive analysis of the country's industrial sector in order to better understand the current adoption of Industry 4.0/5.0 technologies by Italian small and medium-sized businesses.

Italy ranks 18th out of 27 EU Member States in the 2022 edition of the Digital Economy and Society Index (Figure 1)[3]. Italy ranks 8th within the EU in terms of digital technology integration, with a majority of Italian SMEs possessing at least a basic level of digital intensity (60%, surpassing the EU average of 55%). However, the adoption of specific technologies varies across the board. Due to legislative interventions, nearly all Italian enterprises (95%) utilize e-invoices. The country also excels in the adoption of cloud services, with 52% of enterprises leveraging this technology (well above the EU average of 34%). While the usage of ICT for environmental sustainability is fairly common among Italian enterprises, it falls slightly below the EU average. On the other hand, the utilization of big data is minimal (9% of Italian enterprises compared to the EU average of 14%), as is the implementation of AI-based technologies (6% of Italian enterprises compared to the EU average of 8%). Although e-commerce uptake has increased from 2020 to 2021, reaching 13%, it still lags behind the EU average. The proportion of SME turnover attributed to e-commerce and the percentage of SMEs engaged in cross-border sales have seen no significant rise. Italy's main initiative to encourage the adoption of digital technologies among enterprises is the National Plan 'Transition 4.0'. Tax incentives under 'Transition 4.0' are supported by the Recovery and Resilience Plan (EUR 13.4 billion) and the complementary national fund (EUR 5.8

[2] Zheng, T., Ardolino, M., Bacchetti, A. and Perona, M. (2023), „The road towards industry 4.0: a comparative study of the state-of-the-art in the Italian manufacturing industry", Benchmarking: An International Journal, Vol. 30 No. 1, pp. 307-332. https://doi.org/10.1108/BIJ-01-2021-0056).

[3] (DESI 2022)

billion), with a Scientific Committee overseeing the economic impact of the tax credits throughout their implementation. The Recovery and Resilience Plan envisaged the strengthening of the national network of technology transfer centres, expected to provide services on advanced digital technologies to 4 500 SMEs. In November 2021, Italy adopted the Strategic Program on Artificial Intelligence 2022-2024, outlining 24 policy initiatives structured along 3 areas: (i) strengthening competences and attracting talent; (ii) expanding funding of advanced research in AI; and (iii) favouring the adoption of AI and its applications. The strategy builds on existing research communities and infrastructures and addresses weaknesses such as the difficulty to attract foreign talent and the poor performance when it comes to business spending on R&D, patenting and AI applications.

Italian small and medium-sized enterprises are lagging behind large companies in their digital investments growth trend. In 2022, small businesses saw a 2.5% increase in digital spending, medium-sized businesses had a 4.1% increase, and large businesses had a 5.9% increase. The correlation between company size and digital expenditure is evident, with larger organizations investing more in digitalization. The North West and Central Regions of Italy lead in technology spending, accounting for nearly 62% of total expenditure. Nationally, the digital market is projected to grow by 3.1% in 2023, with estimates for 2024-2026 showing even stronger growth thanks to lower inflation impact and increased resources from the National Recovery and Resilience Plan for digitization. An average annual growth rate of 4.5% is expected, reaching almost 92 billion euros by 2026.

The ICT sector in Italy has seen a slight increase in the number of companies registered, with innovative ICT SMEs growing by 11.4% and ICT startups decreasing slightly by -1.34%. Despite this slowdown, the combination of startups and innovative SMEs in the ICT sector remains more dynamic compared to other sectors. These companies focus on high-tech products and services such as app development, cloud computing, cybersecurity, and more. A study by ANITEC-ASSIFORM shows that the main business sectors for these companies include digital solutions, IoT solutions, artificial intelligence, Industry 4.0, and Mobile apps.

Despite the potential for growth, Italian businesses, especially smaller ones, underutilize Artificial Intelligence (AI) systems. Only 6.2% of businesses with at least 10 employees reported using AI, compared to 8% in the EU, with small businesses at 5.3% and large businesses at 24.3%. Understanding these trends and promoting technological innovation is crucial for driving competitiveness in the ICT sector and beyond.

1.2.3. Estonia

Estonia's manufacturing industry is the largest sector by volume of the Estonian economy. In 2021, industrial companies accounted for about 15% of the GDP and employed around 120 000 people across Estonia (nearly a fifth of the total workforce). Indirectly, the industry's supply chains employ another 240 000 workers, which, together with direct jobs, accounts for more than half of employment in Estonia. Depending on the year, the contribution of manufacturing companies to Estonia's export turnover is around ⅔[4]

However, GDP per inhabitant in Estonia was about 87% of the EU average. Also productivity and value added per person employed in the industrial sector are below the EU average.

Statistics also show that Estonia is driven by SMEs (with less than 250 persons employed).

The business economic contribution made by SMEs was particularly notable in Estonia, where SMEs provided more than 75.0 % of the value added in the non-financial business economy. The contribution of micro enterprises (employing fewer than 10 persons) was high too.[5]

[4] Tööstuspoliitika 2035 https://www.mkm.ee/ettevotlus-ja-innovatsioon/toostus/toostuspoliitika
[5] Key figures on Europe, 2023 edition https://ec.europa.eu/eurostat/web/products-key-figures/w/ks-ei-23-001

Estonia ranks 9th of 27 EU Member States in the 2022 edition of the Digital Economy and Society Index (DESI). Estonia is a front-runner in some DESI indicators. In particular, Estonia is a global leader in the digitalisation of public services and continues to invest heavily in this area.

Estonia ranks 8th in the Human capital dimension. 56% of the population has at least basic digital skills while 28% has above basic digital skills. In both these indicators, Estonia performs only slightly better than the EU average. The country does rank third in the EU for the number of ICT specialists, as 6.2% of the total workforce is an ICT specialist. However, while this is significantly higher than the EU average of 4.5%, this share has not grown since 2021. The high proportion of ICT specialists is fuelled by a high number of ICT graduates, accounting for 8.4% of all graduates in 2020. This is the highest percentage in the entire European Union. However, the gender gap persists – even if it is smaller than the EU average – as only 23% of ICT specialists are women.

On connectivity, the country's fixed and mobile broadband take-up is high. Furthermore, Estonia scores above the EU average as regards overall fixed Very High Capacity Network (VHCN) coverage, although it is still unavailable to many households in rural areas.

DESI report (Figure 1) demonstrates that businesses are not yet reaping the full benefits of the digital economy. Despite some innovative companies driving the Estonian business ecosystem, more traditional businesses and Small and Medium-sized Enterprises (SMEs) are lagging behind. Most businesses rarely use advanced technologies, with for example only 10% of companies using big data and 3% using Artificial Intelligence (AI) solutions, which is below the 75% objective of the Digital Decade.[6]

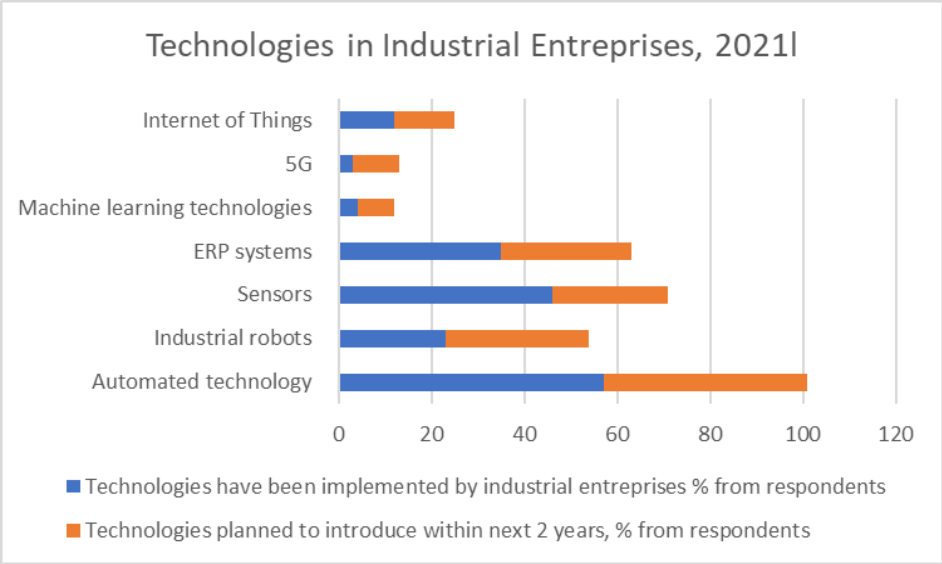

Figure 2. Technologies in Industrial Entreprises, 2012, Estonia.

Source: Swedbank 2021

Survey among 269 Estonian industrial enterprises in 2021 demonstrated that the majority of respondents see technological progress in the automation of production, the introduction of sensors and the use of industrial robots.[7]

[6] Estonia in the Digital Economy and Society Index https://digital-strategy.ec.europa.eu/en/policies/desi-estonia

[7] Swedbank, 2021 swedbankitoostusettevoteteuuring2021-210726110347 PDF (www.tartu.ee)

CHAPTER 2. CASE STUDIES ANALYSIS – NATIONAL LEVELS

Introduction

The aim of the case study analysis (direct interviews with the entrepreneurs with the use of a written questionnaire) was to collect information from the companies on the aspect of how advanced they are in the area of Industry 4.0. The Ready4I5 partnership was interested in collecting information on which competences are crucial in Industry 4.0 applied in the companies. If they have not incorporated any competences so far, it was important to find out the reasons for such an attitude. The results achieved from the case study analysis are described below. The questionnaires from all partner countries are included in the Appendix 1 (only in English).

1.1. Poland

The case study analysis in Poland was performed for 5 companies. The authors will not give the names of the companies due to the request of the companies. The companies are specialised in automation, robotics, or information systems.

The representatives of the companies were asked to respond to the questions according to the questionnaire attached as Appendix 1.

The first group of questions concerned technical competences. The companies were asked how advanced they are in the technical areas indicated in the questionnaire.

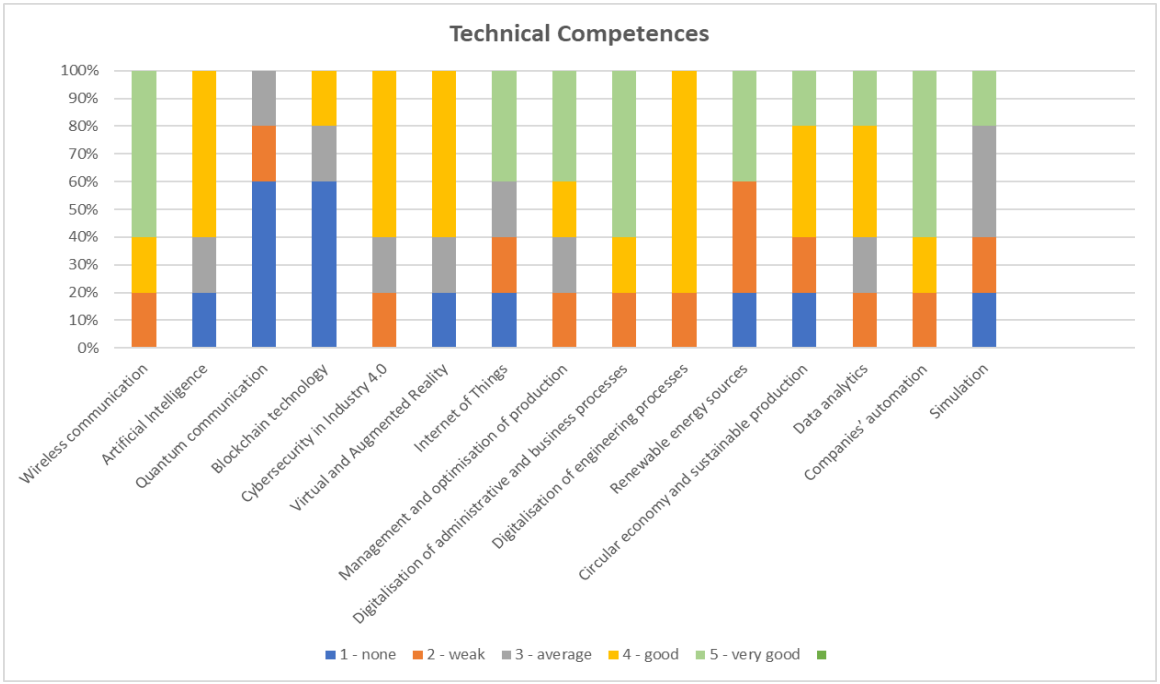

Chart 1. Technical competences.

Source: Authors.

As it can be seen from Chart 1, most of the companies are not familiar with such competences as quantum communication, or blockchain technologies. There could be several reasons why some companies may not be familiar with or actively involved in quantum communication and blockchain technologies:

Complexity and Specialization: Quantum communication and blockchain technologies are relatively complex and specialised fields. Not all companies may have the expertise or resources to understand and implement these technologies effectively. Companies often focus on their core competencies, and if these technologies do not align with their business goals, they may not invest time and resources in exploring them.

Maturity of Technologies: Quantum communication and certain aspects of blockchain technology are still in the early stages of development and may not have reached widespread commercial adoption. Companies might be hesitant to invest in emerging technologies until they become more mature, stable, and proven.

Resource Constraints: Smaller companies, in particular, may face resource constraints, both in terms of finances and skilled personnel. Exploring and adopting cutting-edge technologies like quantum communication and advanced blockchain solutions can be resource-intensive, making it challenging for some companies to prioritise these endeavours.

Regulatory Uncertainty: The regulatory environment around quantum communication and blockchain technologies is evolving. Some companies may be hesitant to invest in technologies that are subject to uncertain or rapidly changing regulations. Regulatory uncertainty can create challenges for businesses trying to navigate legal and compliance frameworks.

Risk Aversion: Companies, especially those in more traditional industries, may be risk-averse when it comes to adopting new and unproven technologies. Quantum communication and blockchain, being relatively new and disruptive, may be viewed as risky endeavours, leading some companies to adopt a wait-and-see approach.

Lack of Awareness: In some cases, companies may simply lack awareness of the potential benefits that quantum communication or advanced blockchain solutions can offer to their specific industry or business model. Education and awareness campaigns in the industry may help overcome this barrier.

Existing Technological Investments: Companies may have made significant investments in existing technologies and infrastructure. Shifting to quantum communication or blockchain may require substantial changes, and companies may be reluctant to disrupt their current systems unless there is a clear and compelling reason to do so.

The most advanced competences are related to *wireless communication* and *automation in the company*. This can be related to the fact that wireless communication has been existing for many years now and it is not very expensive technology. The same with automation. For many years the companies have been changing the technologies from manual to automated ones in order to be more competitive on the market. What is more, digitalisation of administrative and business processes are also visible in companies. It is caused by the following reasons:

Efficiency and Productivity: Digitalization streamlines and automates many administrative tasks, reducing manual efforts and the potential for errors. This leads to increased efficiency and productivity as processes can be executed faster and more accurately.

Cost Savings: Automating administrative processes often results in cost savings by reducing the need for manual labour, paper-based documentation, and other traditional operational expenses. Digitalization can also optimise resource allocation and minimise waste.

Improved Accuracy and Reduced Errors: Automated systems reduce the likelihood of human errors in data entry, calculations, and other routine tasks. This can enhance the accuracy of business processes, leading to more reliable and consistent results.

Real-time Analytics and Reporting: Digital systems provide the capability for real-time data analysis and reporting. This enables companies to make informed decisions based on up-to-date information, fostering agility and responsiveness in a dynamic business environment.

Customer Experience Improvement: Digitalization often extends to customer-facing processes, leading to improved customer experiences. From online transactions to efficient customer service, digitalization can enhance interactions, leading to greater customer satisfaction.

Flexibility and Scalability: Digital solutions offer flexibility and scalability, allowing companies to adapt quickly to changing business requirements. As companies grow, digitised systems can easily scale to accommodate increased data volumes and operational complexity.

Competitive Advantage: Embracing digitalization can provide a competitive advantage in the market. Companies that leverage technology effectively can respond faster to market changes, innovate more rapidly, and differentiate themselves from competitors.

The companies were asked to indicate 5 most important competencies in the area of technical competencies. They were diversified, but some of them were repeated such as: digitalisation of administrative and business processes; data analysis; cybersecurity. These are competences which should be visible in every technological company. What is more, the companies indicated them because they are probably relatively cheap to be achieved and there is no need to cover any additional costs.

The second part of the questionnaire was related to personal competences (Chart 2).

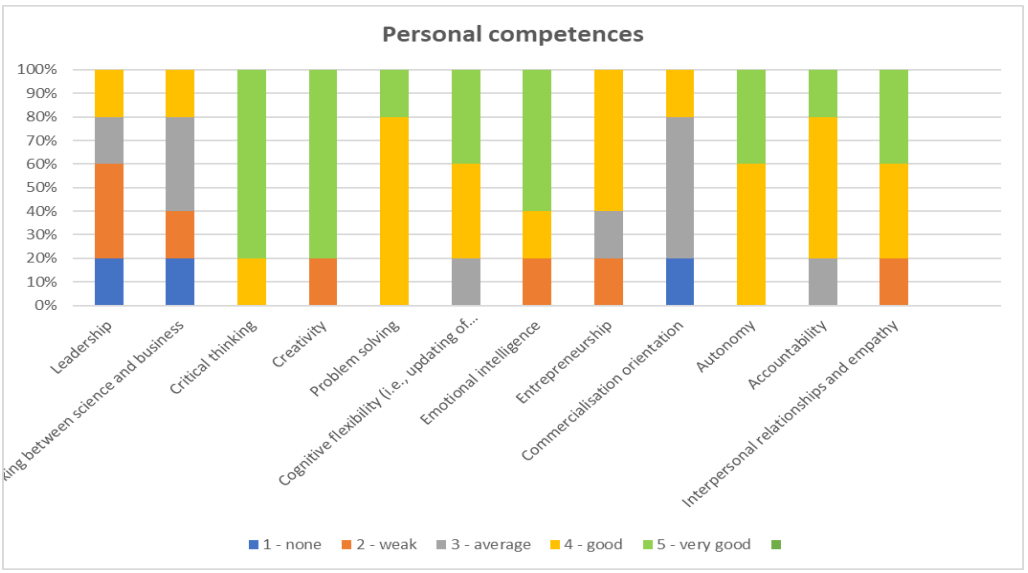

Chart 2. Personal competences.

Source: Authors.

Among personal competences this is creativity which is the most developed in the tested companies. It can be done due to several reasons:

Innovation and Product Development: Creativity is the driving force behind innovation. Companies that foster a creative culture are better positioned to develop new products, services, or solutions that meet evolving customer needs and preferences. Innovations often give businesses a competitive edge in the market.

Problem Solving: Creative thinking enables employees to approach challenges and problems with fresh perspectives. Creative problem-solving can lead to more effective and unconventional solutions, helping companies overcome obstacles and navigate complex issues. Looking at Chart 2, it is also possible to see that the competence "problem solving" was assessed as 4 - good, so the companies have this competence well developed.

Adaptability to Change: In today's dynamic business environment, companies need to adapt to rapid changes in technology, market conditions, and consumer behaviours. Creativity fosters a mindset that embraces change and encourages employees to find innovative ways to navigate uncertainty.

Competitive Advantage: Creative ideas often lead to the development of unique products, services, or business processes that set a company apart from its competitors. This differentiation can be a powerful source of competitive advantage, attracting customers and fostering brand loyalty.

Market Responsiveness: Creative companies are better equipped to respond to emerging trends and shifts in the market. They can quickly adapt their strategies, offerings, and customer experiences to stay ahead of the competition and meet evolving customer expectations.

Long-Term Sustainability: Creativity is essential for long-term business sustainability. Companies that continually innovate and adapt are better positioned to thrive in the face of evolving market conditions, technological advancements, and global challenges.

Other competences well developed are, among others, responsibility and accountability, whereas the worst developed are leadership and commercialisation orientation. These responses come from the fact that the interviewees were not the owners of the companies and for them these competences were not so important. On the other hand, they are in fact crucial if we want to have the team well led and the level of the product sales quite satisfied.

When asking for the identification of the most important personal competences, the respondents indicated, among others, autonomy, responsibility, relations between people in the company, creativity, entrepreneurship, and empathy. It is then possible to see that soft competences are very important even in technological companies, not only in services or training.

The next part of the questionnaire was to get the feedback on managerial competences (Chart 3).

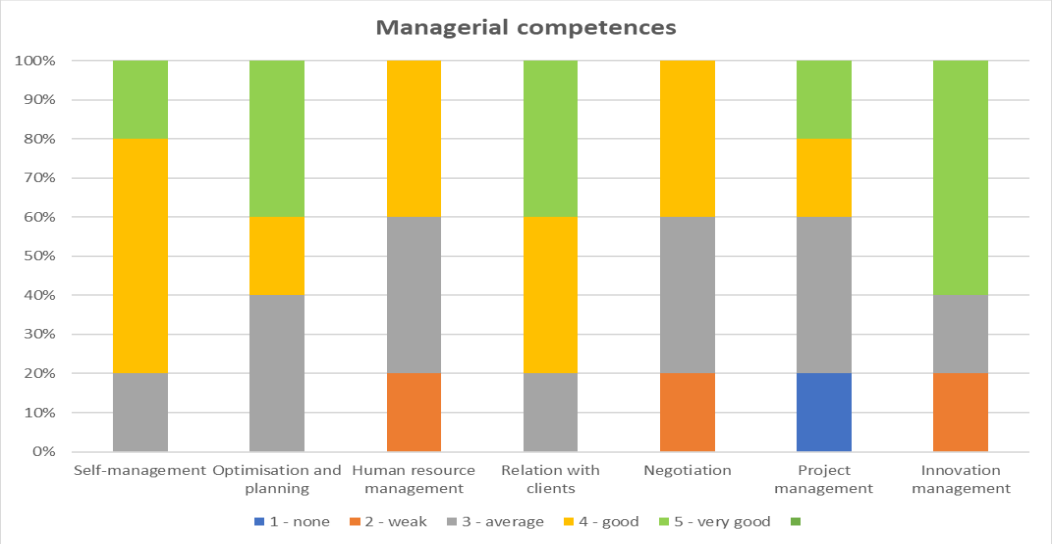

Chart 3. Managerial competences.

Source: Authors.

Chart 3 shows that managerial competences are well developed. Most of them are at average level, but many competences are also perceived at level 4, and 5. Only in one company project management is assessed as very weak, but it can come from the fact that the company uses very rarely public funding and it is not directed to develop projects with other institutions.

The respondents were asked to indicate 3 competences perceived as the most important. They are: self-management, optimisation and planning, relations with clients, project management, innovation management. From these responses it is not possible to indicate one or two crucial competences in terms of managerial competences. It can be then assumed that the whole managerial area is important for good management of the company.

The last part of the questionnaire was to ask the respondents about the equipment of the company and their preparedness for the Industry 4.0 era (Chart 4).

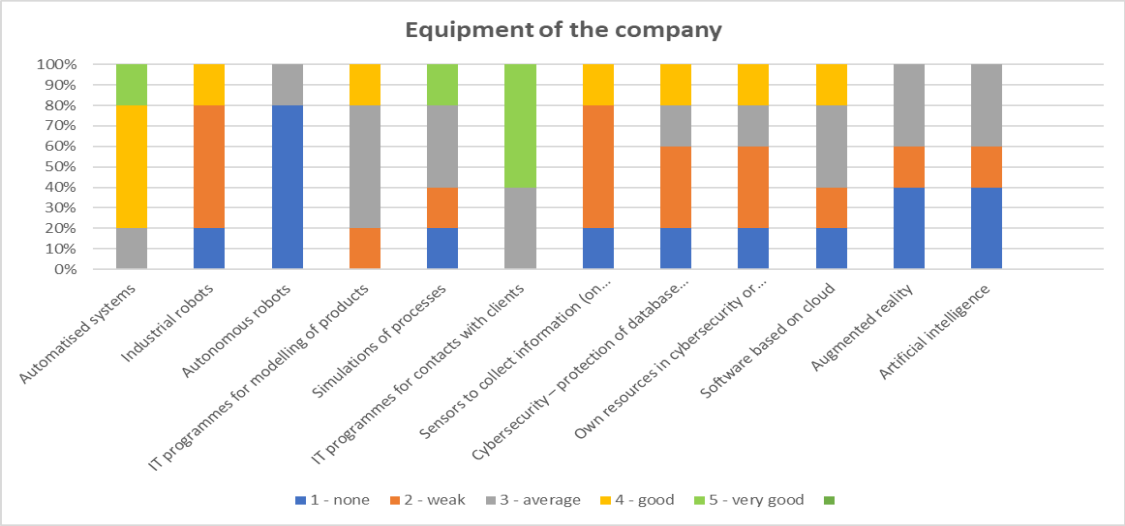

Chart 4. Equipment of the company.

Source: Authors.

As Chart 4 shows the companies suffer from the lack of autonomous robots, augmented reality, and artificial intelligence. It can be related to the costs which should be spent to achieve this. Companies may suffer from the lack of autonomous robots, augmented reality, and artificial intelligence due to missed opportunities for increased efficiency and productivity. These advanced technologies have the potential to automate and optimise various processes, reducing manual labour, minimising errors, and enhancing overall operational performance. The absence of these technologies can result in higher operational costs, slower decision-making processes, and a diminished ability to adapt to rapidly changing business environments. Moreover, companies may face increased competition from those leveraging autonomous robots, augmented reality, and artificial intelligence to gain a competitive edge in innovation, customer experience, and market responsiveness. The lack of adoption may hinder long-term sustainability and limit the ability to capitalise on the transformative benefits these technologies offer.

Chart 4 confirms that the equipment of the companies is perceived as average. In most cases they are able to dispose of IT programmes for contacts with the clients, but such programmes are available for many years now, and they are perceived as basic equipment of almost all companies on the market.

To finalise the questionnaire, the respondents were asked to identify the level of the advancement in the area of Industry 4.0 (Chart 5).

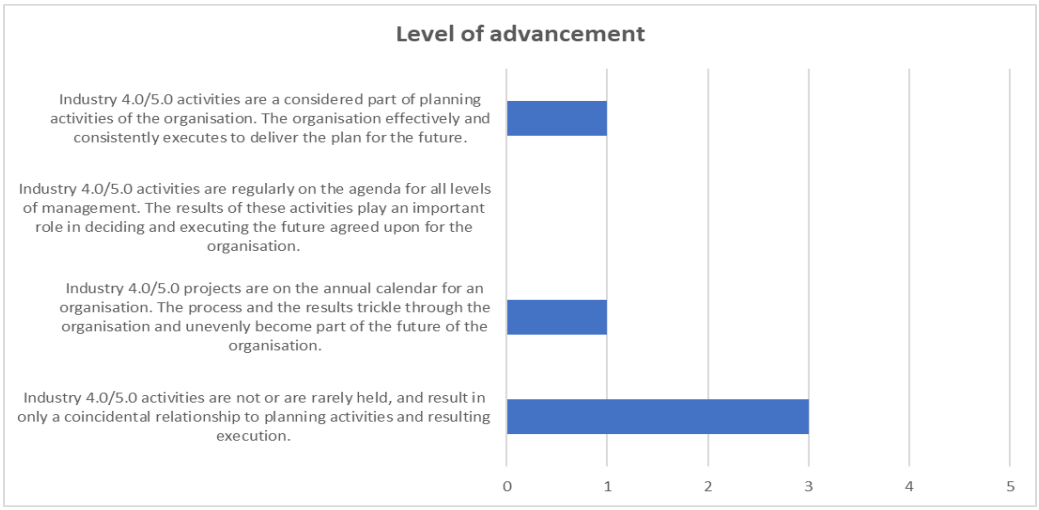

Chart 5. Level of advancement in Industry 4.0/5.0 activities.

Source: Authors.

1.2. Italy

The case study conducted in Italy involved analysing five companies within various industries, including automotive, car equipment manufacturing (specifically tire changers and wheels), sawing machine manufacturing, and cloud services and IT . The identities of the companies have been kept confidential at their request. The companies ranged in size, with one being a larger company with up to 300 employees, two smaller companies between 1-9 employees, two medium-sized companies with 51-250 employees. Most of the companies have been established since the 19th century, with a few founded in the early 2000s and one in 2021. Most of the respondents were male (4 out of 1) and held positions as owners of the companies or department managers. Four out of the five companies belonged to the production sector, while one was a research and development innovative start-up.

The representatives of the companies were asked to respond to the questions according to the questionnaire attached as Appendix 1.

The first group of the questions concerned technical competences. The companies were asked how advanced they are in the technical areas indicated in the questionnaire.

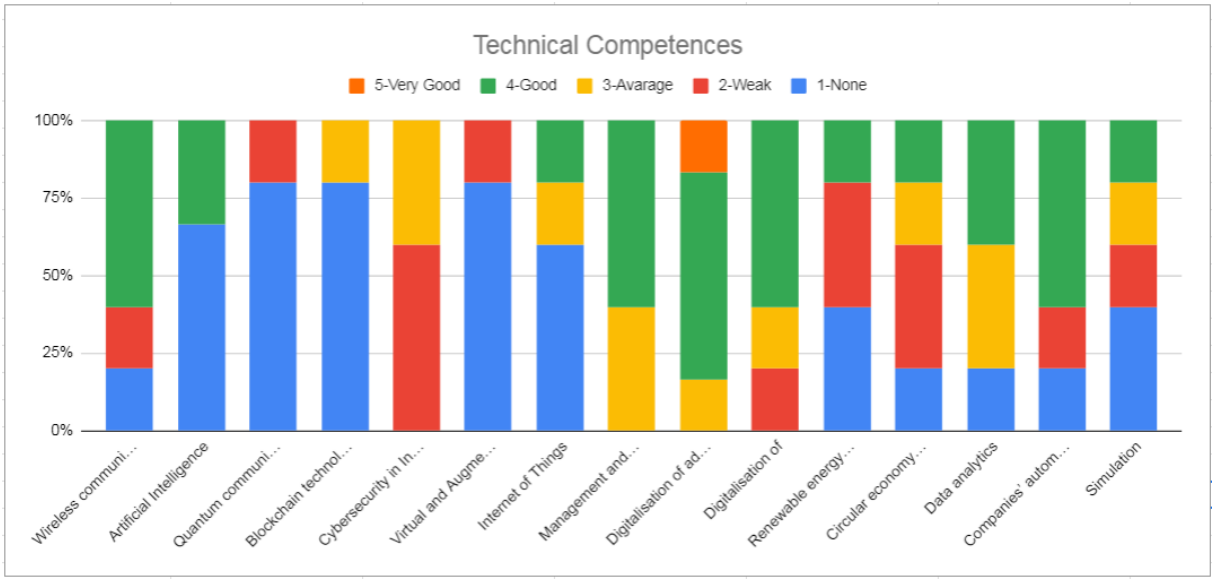

Chart 6 Technical competences in Italian companies.

Source: authors

The graph clearly indicates a significant lack of key competences in the companies interviewed, including Artificial Intelligence, Quantum communication, Blockchain technology, Virtual/ Augmented reality, Cybersecurity, Internet of Things, and Renewable Energy and Circular Economy. This deficiency can be attributed to the slow adoption of Industry 4.0 principles by most companies, signalling that they are still in the early stages of this transformative process. The lack of key competences in the companies interviewed could include a potential loss of competitive advantage, decreased innovation capabilities, heightened vulnerability to cyber attacks, and a failure to capitalise on emerging technologies that could drive growth and sustainability. All surveyed companies view digitalization in administrative, engineering processes, and data analytics as either average or advanced, indicating that both small and big companies are effectively utilising digital technology.

The companies surveyed have successfully implemented existing competencies, but there is still a need for the adoption of more advanced skills and knowledge. In conclusion, it is clear that while companies have made progress in adopting digital technologies in some areas, there is a significant gap in key competencies related to emerging technologies. This lack of expertise could have far-reaching consequences for the companies in terms of competitiveness, innovation, cybersecurity, and sustainable growth. It is imperative for companies to invest in upskilling their workforce and embracing Industry 4.0 principles to stay ahead in today's rapidly evolving digital landscape. Failure to do so may result in missed opportunities and potential threats to their long-term success.

In Question 2, the companies were asked to rank personal competences. The overview of the answers are provided in the chart below.

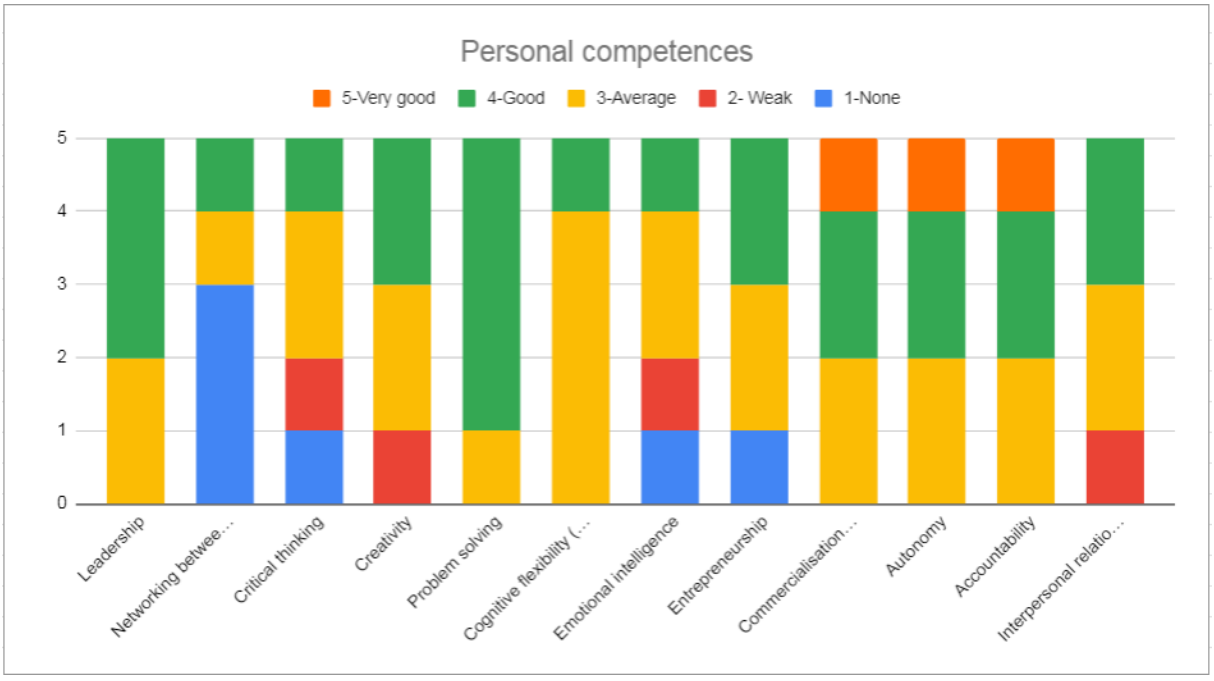

Chart 7. Personal competences.

Source: Authors.

The responses suggest that companies are generally pleased with employees' personal competencies, particularly in areas such as leadership, problem-solving, autonomy, accountability and Commercialisation orientation . The most challenging competencies appear to be those related to networking between science and business, as well as critical thinking and emotional intelligence. Networking between science and businesses is often lacking due to a lack of communication and collaboration between the two sectors. Companies may also lack the resources and expertise needed to effectively network with scientific institutions. However, improving networking skills

between science and businesses can lead to numerous benefits including fostering innovation, driving the development of new products and technologies, and increasing competitive edge in the market. Strategic partnerships and research collaborations can also expand a company's reach and capabilities, ultimately leading to sustainable success in the marketplace. It is crucial for companies to prioritise networking with the scientific community in order to stay ahead of the curve and drive growth in today's competitive business environment. Interpersonal relationships, and empathy, as well as creativity, are competencies that are lacking within the interviewed companies. Many companies prioritise technical skills, such as programming or data analysis, when hiring employees, which can lead to the oversight of important soft skills like emotional intelligence and empathy. To address this issue, companies should actively prioritise and support the development of these essential skills among their employees. This can be accomplished through training programs, mentorship opportunities, and creating a positive company culture that values these competencies.

In Question 3, the companies were asked to evaluate their managerial competences. The overview is presented in the Chart below.

Chart 8. Managerial competences.

Source: Authors.

Chart 8 indicates that the majority of managerial competences are well-developed, with most being rated at levels 3 and 4. Only two respondents identified Human Resource Management and Innovation Management as weak skills. When asked to identify the most important competences, respondents highlighted optimization and planning, client relations, project management, and negotiation. This suggests that there is not one or two stand-out competences, but rather a combination of skills that are crucial for effective management within the company. It can be inferred that a broad range of managerial competencies are necessary for successful management.

In Question 4 the companies were asked about the equipment in use within the production facilities. The answers can be found from Chart 9.

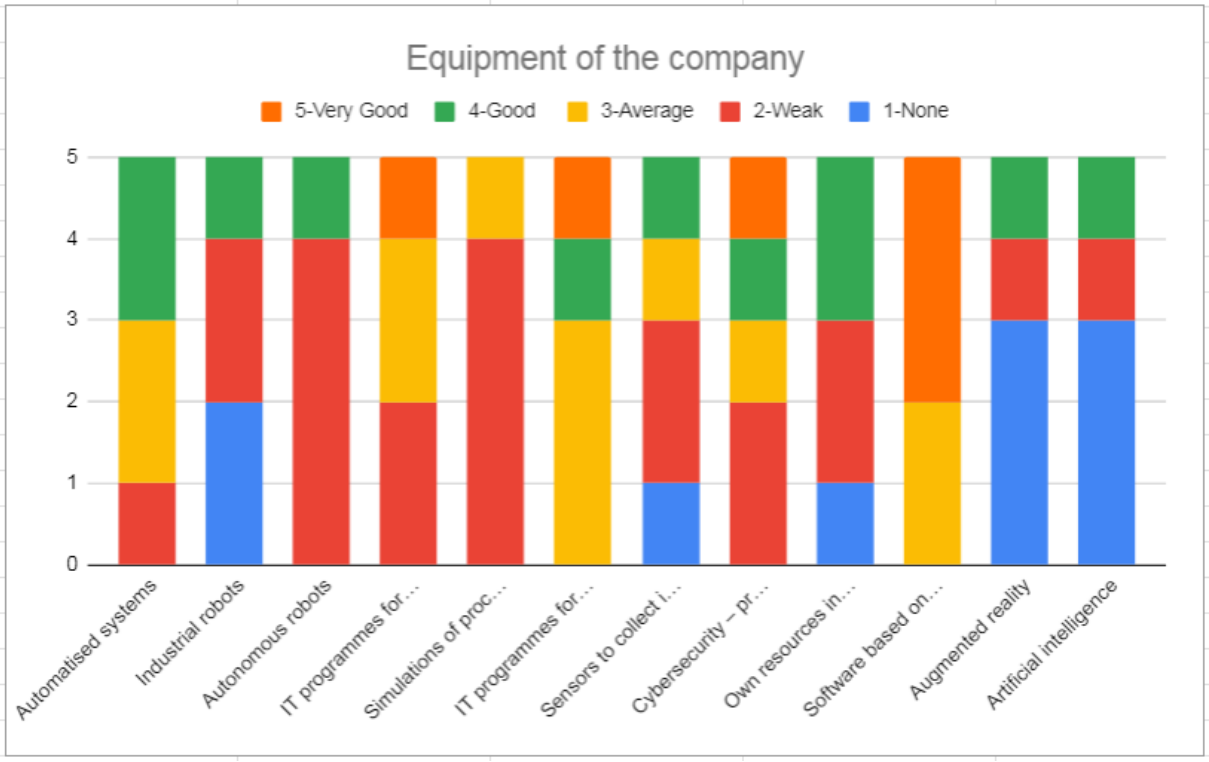

Chart 9. Equipment of the company.

Source: Authors.

According to the chart provided, a large number of companies surveyed lack access to tools, machinery, and technological equipment. Autonomous robots, industrial robots, augmented reality, and artificial intelligence tools are particularly scarce among the companies surveyed. Additionally, there is minimal usage of technological machinery such as sensors to collect information, cybersecurity resources, and process simulations. This low availability of high-tech equipment suggests that these companies are not engaging in technologically supported operations.

However, it is worth noting that IT programmes for contacts with clients, Software based on cloud, and automated systems are more commonly utilised in production and management processes. This disparity in usage could be attributed to economic constraints, as many managers and company owners may not fully comprehend the long-term benefits of investing in high-tech equipment and innovative technology. This lack of investment in technology could hinder the company's overall growth and sustainability in the long run.

As the final question, the participants were asked to assess the level of advancement regarding the principles of Industry 4.0. The results can be seen from Chart 10.

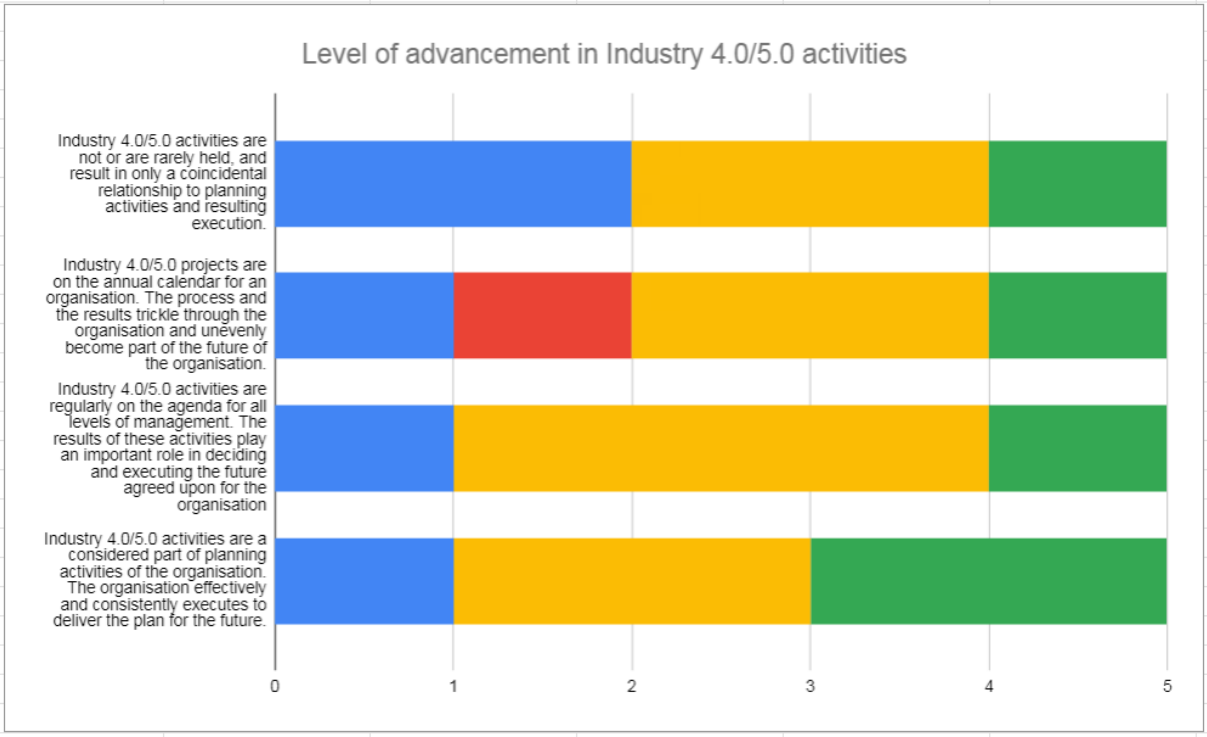

Chart 10. Level of advancement in Industry 4.0/5.0 activities.

Source: Authors.

1.3. Estonia

The case study analysis in Estonia was carried out by sending a questionnaire to 5 companies, all in the field of manufacturing. The authors will not give the names of the companies to protect both the business interests and confidentiality of the participants.

The companies are specialised in different industries, such as wood industry, food processing, and CNC manufacturing. Most of the companies surveyed were on the bigger side: two of the companies had 251 - 500 workers, two 51 - 250 and one 10 - 50. Both of the biggest companies were established in the 19. century, with the rest founded in the early 2000-s. The respondents were all male and either owners of the company or department managers.

The representatives of the companies were asked to respond to the questions according to the questionnaire attached as Appendix 1.

The first group of the questions concerned technical competences. The companies were asked how advanced they are in the technical areas indicated in the questionnaire. The overview of the answers are provided in Chart 11.

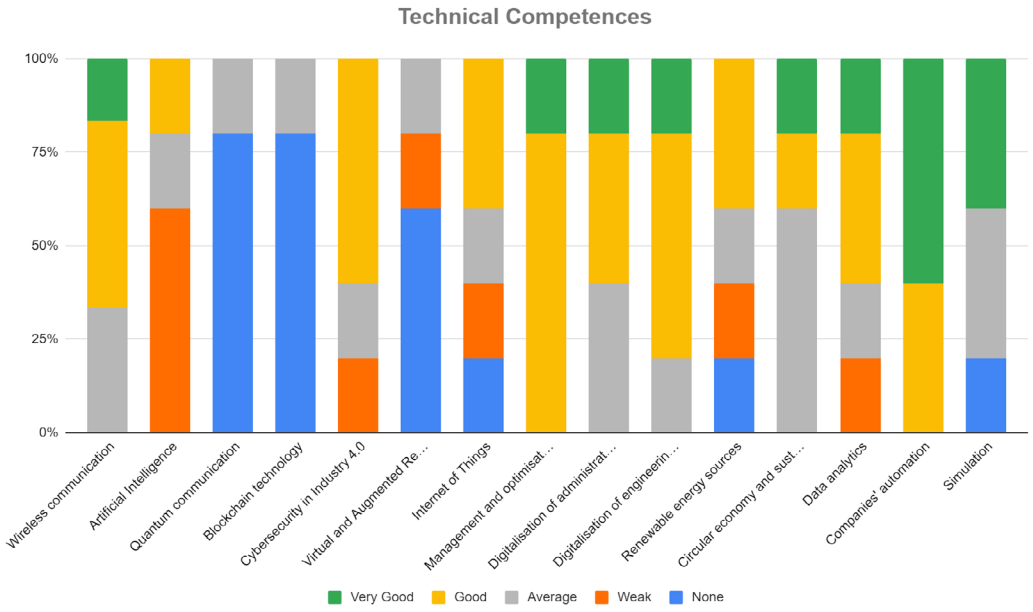

Chart 11. Technical competences in Estonian companies. *Source: authors.*

As can be seen on the graphs, Quantum communication, Blockchain technology, and Virtual/ Augmented reality are all competences that are heavily lacking. This can be explained by the fact that most companies have yet to embrace all the principles of Industry 4.0 as can be later seen from the answers below. Highest focus is on wireless communication, management and optimisation, and companies' automation. It is also notable that all companies have, to varying extent, competences in Artificial Intelligence, hinting towards adaptation of a new and powerful technology.

Digitalisation in both administrative and engineering processes is something that is also something that all the surveyed companies regarded as at least on the average level, meaning that even the smaller companies utilise the full effectiveness of digital technology. With that, cybersecurity still has some ways to come, as in reality the higher the level of digitalisation the higher the emphasis on the security should be. When asked about 5 most important competences, all the companies pointed out the importance of automation as well as optimisation which correlates well with the answers provided in the graph.

Overall, already true and tested competences have been adapted in the surveyed companies while more advanced competences remain to be adapted. The reasons may lie in both lack of human capital as Estonia has a heavy deficit of engineers in the field of manufacturing, and also the lack of resources as the country relies heavily on imported goods and machines.

In Question 2, the companies were asked to rank personal competences. The overview of the answers are provided in Chart 12.

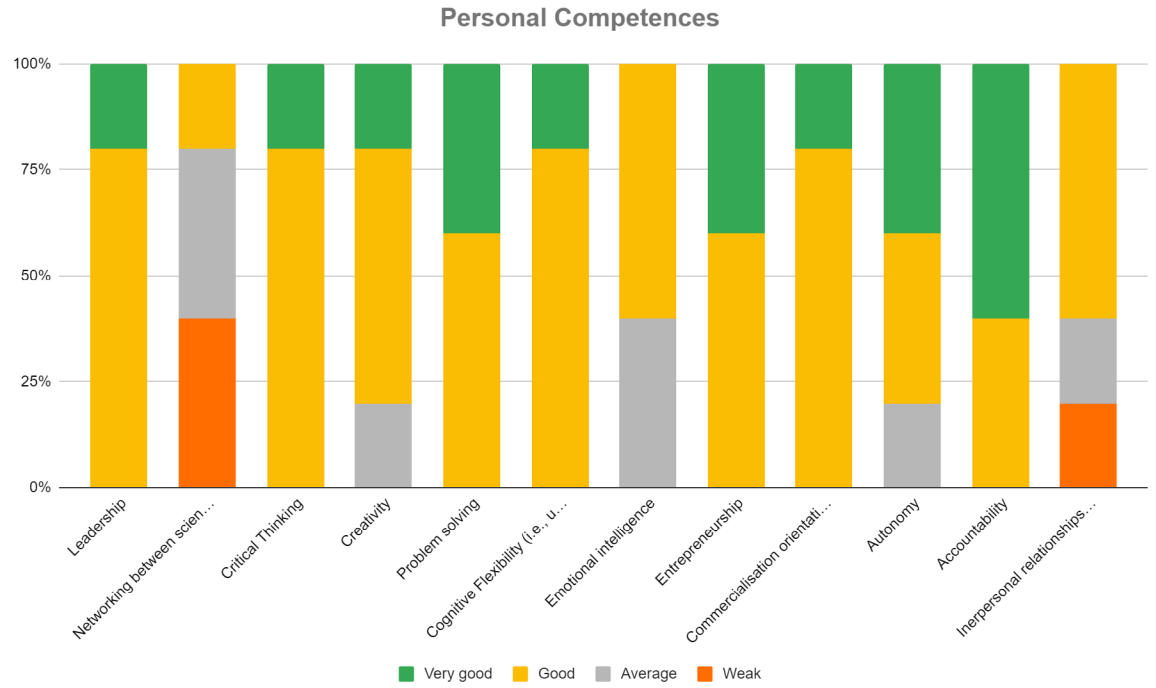

Chart 12. Personal competences in Estonian companies. *Source: authors.*

From the answers we can see that the companies are satisfied with most personal competences, with accountability, entrepreneurship, and critical thinking/cognitive flexibility taking the lead roles as the key competences. The exception being networking between science and businesses, which hints at the modest cooperation between the industrial and scientific sectors. However, it is well known that in order to develop and incorporate new technologies, both practical and theoretical sides must be present. Without research, no new breakthroughs can be made and no new theory is applicable to the real world without corresponding practical case studies.

Combined with not a single "very good" answer regarding emotional intelligence, the lacklustre answers in interpersonal relationships and empathy admit tensions between workers within the companies. This hints at a necessity of educating the workforce not only in professional and technical skills but in soft skills, as well. This is further emphasised by the fact that only two of the five surveyed companies regarded interpersonal relationships and empathy as one of the five most important personal competences, with the others focusing solely on the technical side instead.

In Question 3, the companies were asked to evaluate their managerial competences. The overview is presented in Chart 13.

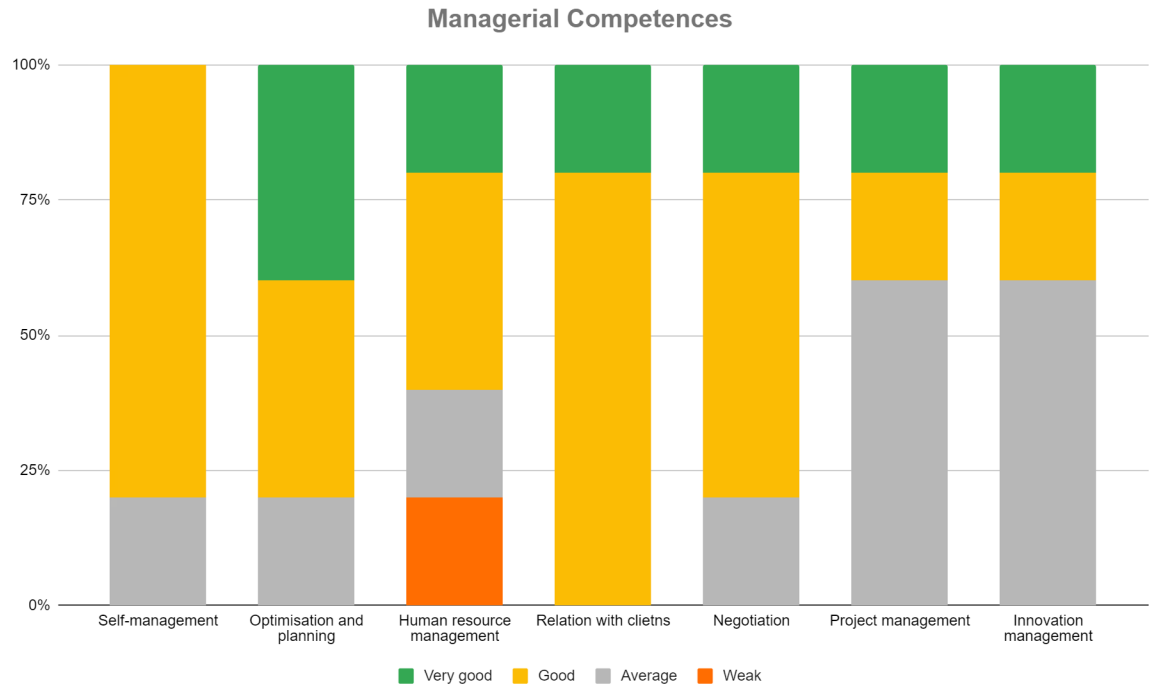

Chart 13. Managerial competences in Estonian companies. *Source: authors.*

From the chart we may observe that the two most well-off competences are optimisation and planning, and relations with clients with negotiation being a close follow-up. From this we can assume that the main aim of the managers within the companies is to optimise and plan the production process. This is further solidified by the answers provided when asked about the five most important managerial competences within the company, as all answers included the optimisation and planning.

Overall, the managerial competences can be considered as satisfactory, with only one company reporting the shortcomings in the human resource management section. However, the lukewarm assessment of innovation management and project management may give insight to the reasons why some of the advanced technical Industry 4.0 principles have yet to be implemented in the production processes within some of the surveyed companies.

In Question 4 the companies were asked about the equipment in use within the production facilities. The answers can be found from Chart 14.

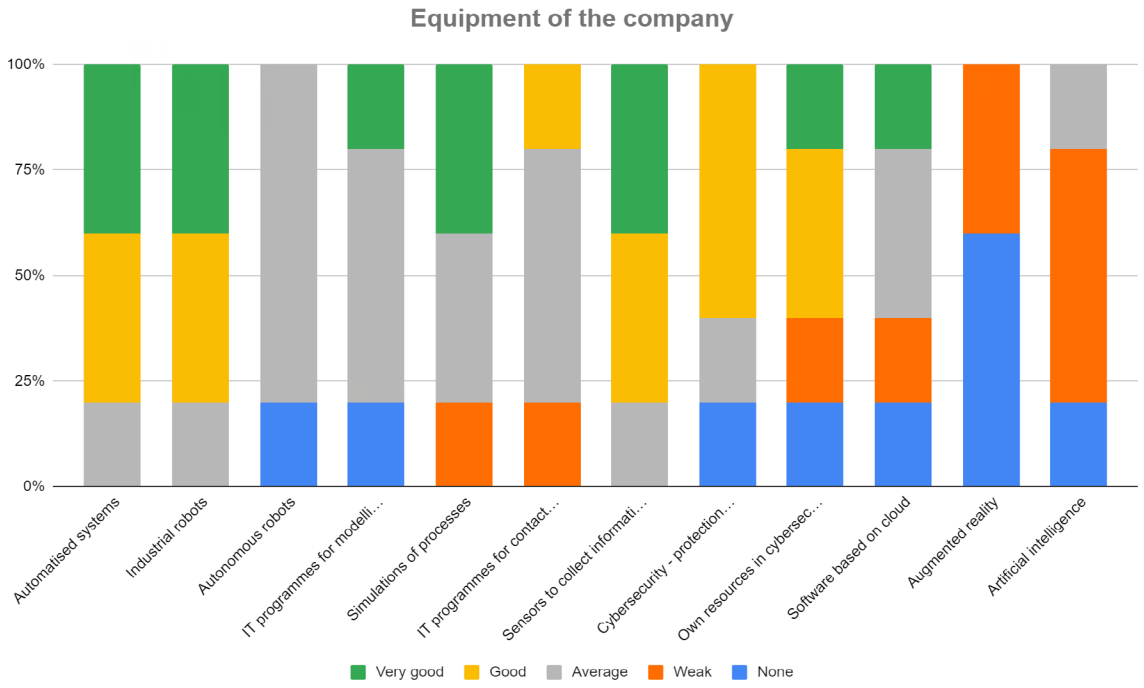

Chart 14. Equipment of the Estonian companies. *Source: authors.*

Several conclusions can be drawn from the answers provided in the graph. First of all, automised systems, industrial robots, and sensors for collecting data are in place in all companies at the minimum of "average" level. This shows that automation is in effect in all companies, even when the level of automation varies. While industrial robots are in use, the level of autonomy of the robots remains to be desired in all surveyed companies, with one of them having no autonomous robots.

Furthermore, Augmented Reality and Artificial Intelligence are both technologies that are either completely absent or implemented on a very small scale. Both of these require not only highly competent staff but also a steep initial investment, making it very difficult for companies with lower turnovers to acquire. It is also worth noting that in order for these technologies to be efficient, a well-organised plan should be in place as well, as most production processes do not need highly sophisticated technologies if they can be achieved through already well-established and true-and-tried means.

Simulation is a field that is at least implemented in all companies, although on different scales/levels, showing a big contrast between the participants. While two companies regarded simulation technology as "very good", the other three reported it as "average" or "weak". This leads to the need of further research, as one possible solution to increase the situation would be to incorporate Virtual/Augmented Reality systems throughout the production process, which is currently lacking in almost all the surveyed companies.

Overall, the technologies in place within the surveyed companies vary greatly, as those with more resources are able to afford more expensive equipment, although more could be done to improve the cybersecurity aspects. This is because the more digitalised production processes become the more emphasis should be placed on the protection of data.

As the final question, the participants were asked to assess the level of advancement regarding the principles of Industry 4.0. The results can be seen from Chart 15.

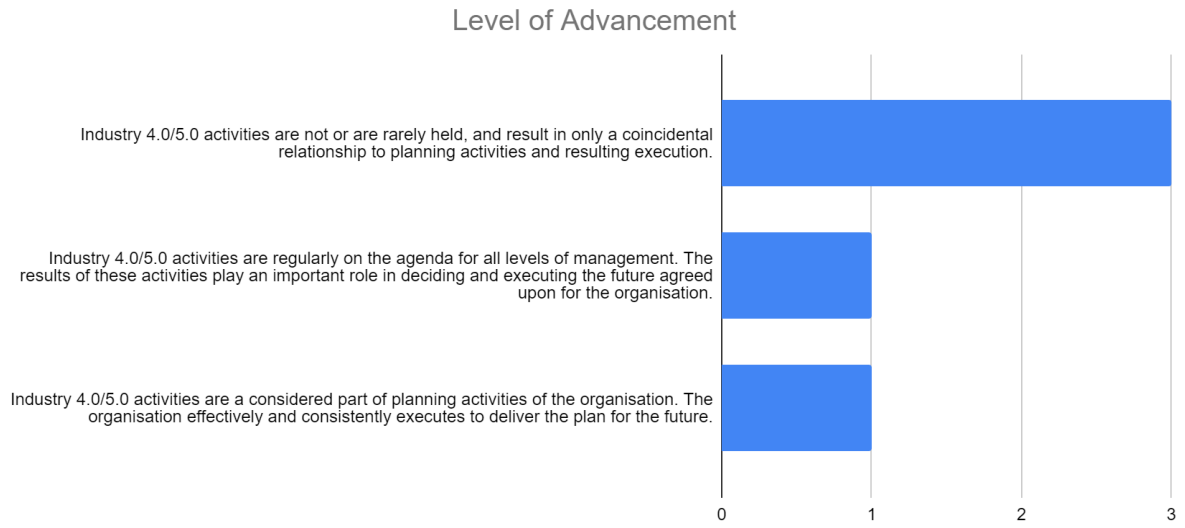

Chart 15. Level of advancement regarding Industry 4.0 principles in Estonian companies. *Source: authors.*

Overall, the principles of Industry 4.0/5.0 are in place in two out of five companies surveyed, with only one of them incorporating said principles in depth. The rest of the three companies report that the approach to Industry 4.0/5.0 is hectic and/or said activities are rarely held, showing that there is still a lot of progress to be made in Estonia.

CHAPTER 3. QUESTIONNAIRE RESULTS ANALYSIS – COMPARATIVE ANALYSIS

In the ever-evolving landscape of Industry 4.0, countries around the world are navigating the complexities of technological advancements and digital transformation to stay competitive in the global market. This chapter delves into a comparative analysis of Industry 4.0 competences advancements in Poland, Italy, and Estonia, three countries with unique economic landscapes and approaches to innovation. By examining the technical, personal, and managerial competences of the staff involved in the activities related to Industry 4.0, and the equipment of the analysed companies, this analysis aims to provide insights into their respective progress in embracing Industry 4.0. Through a comparative lens, we seek to identify key trends, challenges, and opportunities shaping the future of Industry 4.0 competences in these diverse European contexts. This chapter explores the varying trajectories of Industry 4.0 adoption and sheds light on the factors driving innovation and growth in Poland, Italy, and Estonia.

Starting from technical competences, it can be perceived in Poland that wireless communication, digitalisation of administrative & business processes, and companies automation are the competences most developed. On the other hand, quantum communication, and blockchain technologies competences are the least developed. A very similar situation can be observed in Italy in the relation to the competences the least developed. Wireless communication, and management & digitalisation competences are the most advanced. Finally, in Estonia, very similar picture of the competences comparing to Italy. Moreover, the Estonian companies also indicated the virtual and augmented reality competences as not very good developed at this moment.

The competences in wireless communication and the digitalization of administrative & business processes in the realm of Industry 4.0 have seen significant development in Poland, Italy, and Estonia due to several key factors:

Investment in Infrastructure: All three countries have made substantial investments in building robust telecommunications infrastructure, including broadband networks and wireless communication systems. This infrastructure provides the foundation for efficient data transmission and communication across various industrial processes.

Strong ICT Sectors: Each of these countries boast a strong Information and Communication Technology (ICT) sector, characterized by a skilled workforce, thriving research and development (R&D) activities, and a supportive ecosystem for enterprises. This environment has facilitated the development and adoption of wireless communication technologies and digital solutions tailored to Industry 4.0 requirements.

Focus on Digital Transformation: Recognizing the transformative potential of digital technologies, companies in Poland, Italy, and Estonia have increasingly embraced digitalization as a means to enhance efficiency, productivity, and competitiveness. This focus on digital transformation has driven investments in technologies such as data analytics, which is integral to wireless communication and the digitalization of administrative and business processes in Industry 4.0.

The development of competences in quantum communication and blockchain technologies in the context of Industry 4.0 is relatively less advanced in Poland, Italy, and Estonia due to several key reasons:

Complexity and Specialization: Quantum communication and blockchain technologies represent cutting-edge areas of research and development that require specialized expertise and resources.

Limited Infrastructure and Expertise: Building and deploying quantum communication systems and blockchain networks require sophisticated infrastructure and highly skilled professionals with expertise in quantum mechanics, cryptography, and distributed ledger technologies. Poland, Italy, and Estonia may have limited infrastructure and a shortage of experts in these niche areas, hindering the widespread adoption and development of competences in quantum communication and blockchain technologies.

Resource Allocation: Limited resources may be prioritized towards other areas of innovation and economic development, such as traditional manufacturing, information technology, and biotechnology. As a result, investment in research, development, and infrastructure for quantum communication and blockchain technologies may be relatively modest compared to other sectors.

Market Maturity and Demand: The market demand for quantum communication and blockchain solutions in Industry 4.0 applications may still be emerging or niche compared to more mature technologies. Businesses and industries may prioritize investments in technologies with proven track records and immediate tangible benefits, leading to slower adoption and development of competences in quantum communication and blockchain technologies.

The second part of the comparative analysis is related to personal competences. In Poland critical thinking and creativity were assessed at the highest level. Emotional intelligence was also perceived as very well developed. The least developed concerned the relation between science & business and commercialisation orientation. In Italy the companies indicated problem solving, and leadership competences as most developed. On the other hand, similarly to Poland, the networking between science & business was assessed at the lowest level. In Estonia the companies assessed very well the accountability, and entrepreneurship competences. At the relatively good level they also assessed problem solving competence (similarly to Italy). The worst situation is with the networking between science & business competence.

The networking between science & business in the context of Industry 4.0 is often less developed in Poland, Italy, and Estonia due to several interrelated factors:

Historical Context: In many cases, there has been a historical separation between academia/research institutions and industry in these countries. This separation can be traced back to different educational and economic systems in the past, which have led to siloed approaches to innovation and limited collaboration between scientists, researchers, and business leaders.

Limited Funding and Resources: Both scientific research and business innovation require significant investments of funding, resources, and time. However, in some cases, limited public and private funding may constrain the ability of research institutions and businesses to collaborate on mutually beneficial projects. Without sufficient financial support, efforts to build and sustain networks between science and business may falter.

Despite these challenges, there is growing recognition of the importance of fostering closer ties between science and business to drive innovation and economic growth. Efforts to address these barriers may include initiatives to promote entrepreneurship and technology transfer, enhance interdisciplinary education and training, streamline regulatory processes, and incentivize collaboration through funding mechanisms and supportive policies. By overcoming these obstacles, Poland, Italy, and Estonia can unlock the full potential of Industry 4.0 technologies and create a more vibrant ecosystem of innovation and entrepreneurship.

In the next part, the companies assessed the managerial competences. In Poland the highest rates were received by optimisation and planning, and innovation management competences. The lowest

rate was assigned to the project management competence. In Italy almost all competences were assessed at a relatively high level. The weakest rates were received by human resources management, and innovation management. Similarly to Estonia, optimisation and planning competence was assessed very high, whereas human resource management still quite low.

The development of competences in human resource management (HRM) in the context of Industry 4.0 may be comparatively less advanced in Poland, Italy, and Estonia due to several key factors:

Skills Mismatch: Industry 4.0 technologies require a highly skilled workforce with expertise in areas such as data analytics, artificial intelligence, robotics, and cybersecurity. However, there may be a mismatch between the skills demanded by emerging technologies and the skills possessed by the available labour force in these countries. Limited investment in education and training programs tailored to Industry 4.0 competences can exacerbate this skills gap.

Traditional Workforce Structures: Traditional workforce structures and management practices prevalent in Poland, Italy, and Estonia may not align with the dynamic and agile nature of Industry 4.0 environments. Hierarchical organizational structures, bureaucratic processes, and resistance to change can hinder the adoption of innovative HRM practices suited to the needs of Industry 4.0, such as flexible work arrangements, continuous learning, and talent mobility.

Limited Digital HR Infrastructure: The adoption of digital technologies for HRM, such as human capital management systems, talent analytics platforms, and remote work tools, may be less widespread in Poland, Italy, and Estonia compared to more advanced economies. Limited access to and investment in digital HR infrastructure can constrain organizations' ability to effectively manage and optimize their human resources in the context of Industry 4.0.

Finally, the project partners assessed the equipment of the companies. Here, the situation is not so good. The entrepreneurs are very weak in skills for managing autonomous robots, augmented reality, or artificial intelligence. They didn't indicate any element in which they feel very well developed. Similar situation can be observed in Italy and Estonia.

Companies may identify autonomous robots, augmented reality (AR), or artificial intelligence (AI) as the weakest elements due to several reasons:

Complexity and Implementation Challenges: Implementing autonomous robots, AR, and AI technologies often requires significant investment, expertise, and infrastructure. Companies may struggle with the complexity of integrating these technologies into their existing workflows and systems, especially if they lack the necessary technical capabilities or resources. The deployment of autonomous robots, for example, may require extensive programming and testing to ensure safety, reliability, and compatibility with existing equipment.

Skills Gap: Leveraging autonomous robots, AR, and AI effectively requires a skilled workforce with expertise in robotics, computer vision, machine learning, and other specialized fields. However, there may be a shortage of talent with the requisite skills and experience in these areas, particularly in countries like Poland, Italy, and Estonia where the education and training systems may not fully align with the demands of Industry 4.0.

Cost Considerations: The upfront costs associated with acquiring and deploying autonomous robots, AR devices, and AI solutions can be prohibitive for many companies, especially small and medium-sized enterprises (SMEs) with limited financial resources. Additionally, the return on investment (ROI) for these technologies may not always be immediately apparent or guaranteed, making companies hesitant to commit to large-scale deployments.

Integration with Existing Processes: Integrating autonomous robots, AR, and AI into existing business processes and workflows can be challenging, particularly if there is resistance to change or inertia within the organization. Companies may encounter resistance from employees who fear job

displacement or who are unfamiliar with the new technologies, leading to resistance to adoption and implementation.

To summarise, the companies which took part in this research are not still very well advanced with Industry 4.0. It can come from different aspects, especially financial, personal, and technological which are indispensable in order to go further with the development.

WORD BANK

Industry 4.0, is the realization of the digital transformation of the field, delivering real-time decision making, enhanced productivity, flexibility and agility to revolutionize the way companies manufacture, improve and distribute their products (IBM, 2024).

Automation is the application of technology, programs, robotics or processes to achieve outcomes with minimal human input (IBM, 2024).

The Internet of Things (IoT) describes the network of physical objects—"things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet (Oracle, 2024).

Big data is data that contains greater variety, arriving in increasing volumes and with more velocity. This is also known as the three "Vs" (velocity, volume, and variety).

Cyber-physical systems integrate sensing, computation, control and networking into physical objects and infrastructure, connecting them to the Internet and to each other (National Science Foundation, 2024).

A digital twin is a virtual representation of an object or system designed to reflect a physical object accurately. It spans the object's lifecycle, is updated from real-time data and uses simulation, machine learning and reasoning to help make decisions (IBM, 2024).

BANK OF EXERCISES

Exercise 1. Please, choose the correct answer.

1. *What is a key competence required in Industry 4.0?*

a) Carpentry

b) Data analysis

c) Calligraphy

d) Gardening

Answer: b) Data analysis

2. *Which technology is commonly associated with Industry 4.0?*

a) Typewriter

b) Rotary phone

c) 3D printing

d) Fax machine

Answer: c) 3D printing

3. What does IoT stand for in the context of Industry 4.0?

a) Internet of Things

b) Institute of Technology

c) Insight on Technology

d) Island of Tigers

Answer: a) Internet of Things

4. What does "cyber-physical systems" refer to in Industry 4.0?

a) Computers in outer space

b) Robotic pets

c) Integration of physical and digital systems

d) Virtual reality headsets

Answer: c) Integration of physical and digital systems

5. Which of the following skills is essential for navigating Industry 4.0?

a) Horseback riding

b) Social media marketing

c) Juggling

d) Coding

Answer: d) Coding

Exercise 2: Industry 4.0 Skills Assessment

Objective:

The objective of this exercise is to assess candidates' competences and skills relevant to Industry 4.0 technologies and concepts.

Instructions:

- Each candidate will be provided with a set of tasks or scenarios related to Industry 4.0.
- Candidates will be asked to demonstrate their knowledge, problem-solving abilities, and practical skills by completing the tasks or responding to the scenarios.
- Candidates may be required to work individually or in groups, depending on the nature of the tasks.
- Assessors will observe candidates' performance and evaluate their proficiency in key competences such as data analysis, programming, digital literacy, problem-solving, and teamwork.
- Candidates may also be asked to explain their approach, rationale, and decisions during the exercise to assess their critical thinking and communication skills.

Example Tasks/Scenarios:

- Data Analysis Task:

Given a dataset containing manufacturing process data, analyse the data to identify patterns, anomalies, and potential optimization opportunities. Present your findings and recommendations in a clear and concise manner.

- Problem-Solving Scenario:

You encounter a technical issue with an Internet of Things (IoT) device used in a smart factory. Identify the root cause of the issue, propose troubleshooting steps, and implement a solution to resolve the problem effectively.

- Team Collaboration Exercise:

Work collaboratively with other candidates to brainstorm ideas for implementing a new Industry 4.0 initiative within a manufacturing company. Define project objectives, allocate roles and responsibilities, and outline a plan for execution, considering factors such as budget, timeline, and resource constraints.

Evaluation Criteria:

- Technical proficiency in relevant Industry 4.0 technologies and tools.
- Analytical skills and ability to interpret data and draw actionable insights.
- Problem-solving skills and capacity to troubleshoot technical issues.

- Communication skills and ability to articulate ideas, findings, and solutions effectively.
- Collaboration and teamwork skills, including the ability to work effectively in a group setting.

Exercise 3. Transversal skills for an Industry 4.0 entrepreneur

1. What is the importance of creativity in entrepreneurship?

A) Creativity is only important in art, not in business

B) Creativity helps in generating innovative ideas and solutions, setting a business apart from competitors.

C) Creativity has no importance in entrepreneurship

D) Entrepreneurship is only about following existing ideas, not creating new ones

Answer: B

2. What is the role of leadership in entrepreneurship?

A) Leadership in entrepreneurship is not important

B) In entrepreneurship, leadership only involves giving orders and expecting them to be followed without question

C) The role of leadership in entrepreneurship is to micromanage every aspect of the business

D) Leadership in entrepreneurship involves setting a vision, motivating and guiding the team, making strategic decisions, and taking calculated risks.

Answer: D

3. What is the right order of problem solving process?

A) Try, Reflect, Prepare, Define

B) Prepare, Try, Define, Reflect

C) Try and Reflect

D) Define, Prepare, Try, Reflect

Answer: B

4. Preparing to solve the problem might include brainstorming.

A) True

B) False

Answer: A

5. What steps can improve your organisational skills?

A) Delegation of tasks to others

B) Planning and prioritising tasks

C) Documenting and record keeping

Answer: All

6. Workplace flexibility emphasises…

A) The readiness to work under any working conditions

B) The willingness and ability to adapt to change

C) The capacity to agree with any decision

D) The ability to accomplish complicated tasks

Answer: B

7. Creativity in the workplace results in...

A) Streamlining efficiency

B) The ability to attract and retain employees

C) Productivity

D) Better teamwork

Answer: All

8. The method in which each side hives up something of value to help solve a problem.

A. Compromise

B. Consensus

C. Constraint

D. Problem solving

Answer: A

Exercise 4. Industry 4.0: Basic Terms and Knowledge for Future Preparation

1. Which term best describes the core philosophy of Industry 5.0?

A) Efficiency

B) Empowerment

C) Optimization

D) Automation

Answer: B

2. Which is a key objective of Industry 5.0?

A) Minimising human involvement

B) Maximising profit margins

C) Enhancing worker well-being

D) Expanding production capacity

Answer: C

3. What is the primary technology enabling human-machine collaboration in Industry 5.0?

A) Augmented Reality

B) Artificial Intelligence

C) Blockchain

D) Robotics

Answer: A

4. How does Industry 5.0 contribute to sustainability?

A) By reducing energy consumption

B) By minimising waste

C) By optimising resource utilisation

Exercise 5. Industry 5.0 Principles

Objective:

The objective of this learning exercise is to deepen understanding of Industry 5.0 principles and their practical applications in various industries.

Instructions:

- Provide an overview of Industry 5.0 highlighting its focus on human-machine collaboration and the integration of technology with human-centric approaches to manufacturing.
- Ask participants to research the core principles of Industry 5.0. Encourage them to explore topics such as:
  - The role of humans in the production process
  - Technologies enabling human-machine collaboration
  - Benefits of Industry 5.0 for businesses and society
  - Examples of Industry 5.0 implementation in various industries

Example Tasks/Scenarios:

Case study analysis and application of Industry 5.0:

- Ask participants to analyze case studies and identify:
  - How human-machine collaboration is integrated into the production process
  - The impact of Industry 5.0 on productivity, efficiency, and worker satisfaction
  - Challenges faced during the implementation of Industry 5.0 principles and how they were overcome

Brainstorming and problem solving for implementing industry 5.0 practices

- Divide participants into small groups and present them with a hypothetical scenario where a traditional manufacturing company is looking into transition to Industry 5.0 practices.
- Ask each group to find possible solutions and strategies for implementing Industry 5.0 principles in the company, considering factors such as technology adoption, workforce training, and organizational culture.

Evaluation Criteria:

- Elaboration and evaluation skills on the potential implications of Industry 5.0 for the future of work, economic development, and sustainability.
- Communication skills and ability to articulate ideas, findings, and solutions effectively.
- Collaboration and teamwork skills, including the ability to work effectively in a group setting.

Exercise 6. Fill in the Blank: Fill in the blank with the correct words.

1. Investments in __ have been a key factor in the development of wireless communication and the digitalization of administrative and business processes in Industry 4.0 across Poland, Italy, and Estonia.
2. The __ sectors in these countries have fostered the development and adoption of wireless communication technologies and digital solutions tailored to Industry 4.0 requirements.
3. Quantum communication and __ technology competencies are relatively less developed in the context of Industry 4.0 in Poland, Italy, and Estonia.
4. The limited __ and expertise in these niche areas have hindered the widespread adoption and competency development of quantum communication and blockchain technologies.
5. Developing stronger __ between academia and industry is crucial for promoting innovation and economic growth in the context of Industry 4.0.

Word bank:

infrastructure *(1);* blockchain *(3)*; ICT *(2)* networks *(5)*; resources *(4)*

Exercise 7. Choose the correct answer from the choices for each question.

1. Which of the following is the most well-developed technical competency in the context of Industry 4.0 across Poland, Italy, and Estonia?

A. Quantum communication

B. Wireless communication

C. Blockchain technology

D. Virtual and augmented reality

Answer: B. Wireless communication

2. Which personal competency was rated the highest in Poland's Industry 4.0 context?

A. Problem-solving

B. Critical thinking and creativity

C. Entrepreneurial orientation

D. Emotional intelligence

Answer: B. Critical thinking and creativity

3. Which managerial competency was considered the weakest across Poland, Italy, and Estonia in Industry 4.0 context?

A. Optimization and planning

B. Innovation management

C. Project management

D. Personnel management

Answer: D. Personnel management

4. Why are autonomous robots, augmented reality, and artificial intelligence the least developed elements in the equipment of the surveyed companies?

A. Complexity and implementation challenges

B. Lack of skilled workforce

C. High costs

D. All of the above

Answer: D. All of the above

5. What is the main reason for the relatively less developed science-industry collaboration in the context of Industry 4.0 in Poland, Italy, and Estonia?

A. Historical context

B. Limited funding and resources

C. Resistance to change

D. Both A and B

Answer: D. Both A and B

Exercise 7*. Explain and discuss the following topics. Give reasons and examples

1. Explain the key factors how the development of wireless communication has contributed to the digitisation of administrative and business processes in the context of Industry 4.0 in Poland, Italy and Estonia.
2. Discuss why quantum communication and blockchain technologies are less developed in the context of Industry 4.0 in Poland, Italy and Estonia.
3. Describe the challenges faced by Polish, Italian and Estonian companies in integrating autonomous robots, augmented reality and artificial intelligence.

APPENDIX 1.

Q1. Please go through the list of technical competences. Please rank them according to your current situation.

Please rank your choice: from 1 to 5 (5 – acquired by you/the staff; 1 – not acquired by you/the staff) by putting the right number in the provided fields. At the end, rank 5 most important competences.

No	Technical Competences - You/your staff are able to work in the following areas:	Rank (1-5)
1.	Wireless communication	
2.	Artificial Intelligence	
3.	Quantum communication	
4.	Blockchain technology	
5.	Cybersecurity in Industry 4.0	
6.	Virtual and Augmented Reality	
7.	Internet of Things	
8.	Management and optimisation of production	
9.	Digitalisation of administrative and business processes	
10.	Digitalisation of engineering processes	
11.	Renewable energy sources	
12.	Circular economy and sustainable production	
13.	Data analytics	
14.	Companies' automation	
15.	Simulation	

Comments, if any:

Q2 Please go through the list of personal competences. Please rank them according to your current situation.

Please rank your choice: from 1 to 5 (5 – acquired by you/the staff; 1 – not acquired by you/the staff) by putting the right number in the provided fields. At the end, rank 5 most important competences.

No	Personal Competences - You/your staff are able to work in the following areas:	Rank (1-5)
1.	Leadership	
2.	Networking between science and business	

3.	Critical thinking	
4.	Creativity	
5.	Problem solving	
6.	Cognitive flexibility (i.e., updating of knowledge)	
7.	Emotional intelligence	
8.	Entrepreneurship	
9.	Commercialisation orientation	
10.	Autonomy	
11.	Accountability	
12.	Interpersonal relationships and empathy	

Comments, if any:

Q3. Please go through the list of managerial competences. Please rank them according to your current situation.

Please rank your choice: from 1 to 5 (5 – acquired by you/the staff; 1 – not acquired by you/the staff) by putting the right number in the provided fields. At the end, rank 5 most important competences.

No	Managerial Competences - You/your staff are able to work in the following areas:	Rank (1-5)
1.	Self-management	
2.	Optimisation and planning	
3.	Human resource management	
4.	Relation with clients	
5.	Negotiation	
6.	Project management	
7.	Innovation management	

Comments, if any:

PART II: THE EQUIPMENT OF THE COMPANY

*Pl*ease rank your choice: from 1 to 5 (5 – possessed by your company; 1 – not possessed by your company) by putting the right number in the provided fields. At the end, rank 5 most important elements of the equipment.

No	Equipment in your company related to Industry 4.0 environment	Rank (1-5)
1.	Automatised systems	
2.	Industrial robots	
3.	Autonomous robots	
4.	IT programmes for modelling of products	
5.	Simulations of processes	
6.	IT programmes for contacts with clients	
7.	Sensors to collect information (on current place of a machine; on products)	
8.	Cybersecurity – protection of database and systems	
9.	Own resources in cybersecurity or external support	
10.	Software based on cloud	
11.	Augmented reality	
12.	Artificial intelligence	

Comments, if any:

PART III: GENERAL QUESTIONS

In this part, you will clarify how familiar you are with the field "Industry 4.0/5.0".

Please assess the level of the proficiency of your company in the field of Industry 4.0 (maybe 5.0):

- ★ Industry 4.0/5.0 activities are not or are rarely held, and result in only a coincidental relationship to planning activities and resulting execution.
- ★ Industry 4.0/5.0 projects are on the annual calendar for an organisation. The process and the results trickle through the organisation and unevenly become part of the future of the organisation.
- ★ Industry 4.0/5.0 activities are regularly on the agenda for all levels of management. The results of these activities play an important role in deciding and executing the future agreed upon for the organisation.
- ★ Industry 4.0/5.0 activities are a considered part of planning activities of the organisation. The organisation effectively and consistently executes to deliver the plan for the future.

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