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Changes of competencies in the labour market caused by the implementation of Industry 4.0

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Abstract: The digital transformation associated with Industry 4.0 is fundamentally changing the labour market, creating a need for new but also evolving employee competencies. This paper explores the future need for competencies that will be essential for successful employment in this dynamically changing environment. Based on a survey realized among Slovak industrial companies and using the AHP method, key competencies for employees at the operational management level were identified and ranked. The findings show that a successful operational manager must combine hard skills with digital systems and soft skills. The competencies that were identified as realistically the most important are in line with global trends. This confirms that employees who want to be prepared for the future and new challenges must integrate technological literacy with their personal and managerial competencies. Furethermore, the importance of efficient management of logistics processess, including the optimisation of material and financial flows, is increasing, which requires specific competencies in logistic and financial management. The paper highlights the need for companies to invest in education, reskilling and up-skilling of their employees to increase their competitiveness and at the same time to eliminate the factors that prevent them from successfully implementing Industry 4.0 principles and techniques. The paper concludes with an overview of the expected trends in the labour market and highlights the need to prepare for the new challenges and opportunities that Industry 4.0 brings.

1 Introduction

The labour market has been undergoing turbulent changes in recent years. First it was hit by the COVID-19 pandemic, which changed the shape of many jobs and the way they were performed. After the pandemic came rising inflation as a result of the conflict in Ukraine. Industry 4.0, described as the new fourth phase of the industrial revolution, is bringing further fundamental changes to the labour market. In addition to changes in jobs, the requirements for employees and their competencies are also changing.

The key attributes of this industrial revolution are automation, digitalization, high levels of interconnectivity between devices or Big Data analytics. Manufacturing operating under Industry 4.0 conditions is moving from traditional approaches to complex ones that are capable of prediction and decision-making, thus ensuring greater efficiency and flexibility of processes. The implementation of new technologies leads to increased productivity, reduced operating costs and improved product quality [1].

While Industry 4.0 brings many benefits, it also brings challenges, such as cyber security risks and the need to retrain the workforce, which need to be addressed in order to realise the full potential of the next industrial revolution. Industrial companies will need specialists with digital skills, technical skills in AI, Big Data or cybersecurity in particular, but we must not forget soft skills including critical thinking, communication and problem solving, as these are increasingly in demand as core competencies of the modern workforce [2].

The aim of the paper is to find and point out the differences between real competencies and competencies required from employees working in industry under Industry 4.0 conditions.

2 Literature review

Industry 4.0 represents the fourth industrial revolution, which is focused on the digitalization and automation of manufacturing processes through the use of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), machine learning (ML), blockchain, cyber-physical systems (CPS), big data (Big Data) and cloud computing [3]. This concept was first introduced by the German government in 2011 to increase the

competitiveness of manufacturing companies and support the transition to smart manufacturing [4].

Industry 4.0 means the transition from centralized production to decentralized and autonomous production systems where machines and equipment communicate with each other and make decisions based on real-time data analysis [5]. Industry 4.0 is a concept that according to the authors Demirbag and Yildirim (2023), means not only the use of digital technologies in manufacturing, but also the transformation of organizational management, strategy and the entire value chain. Thus, the essence of Industry 4.0 is not only technological innovation, but also the ability of countries and companies to adapt to global changes and use them to increase their competitiveness [2].

2.1 Evolution from Industry 1.0 to Industry 4.0

Industrial revolutions represent major milestones in the development of society, technology and the economy. Each of these revolutions has brought ground-breaking innovations that have fundamentally changed the way people produce, work and live. The gradual transition from Industry 1.0 to Industry 4.0 reflects the continuous technological progress and its impact on the economy and society as a whole [3, 6].

The first industrial revolution, referred to as Industry 1.0, began in the second half of the 18th century. It was characterised by the introduction of mechanisation into production, allowing manual labour to be replaced by machines. The main attributes of this period were the introduction of mechanization into industrial production, the emergence of large factories and centralized manufacturing, the increase in productivity and efficiency through the use of steam-powered machines, the change in the organization of work and the onset of industrialization [7]. Mechanization caused a significant increase in the production and availability of goods. Although production became more efficient, it was still heavily dependent on human labour and the organisation of work in factories, where the first forms of division of labour began to be applied [8].

The second industrial revolution, known as Industry 2.0, was characterised by the introduction of electricity into manufacturing processes and the emergence of mass production. Key attributes of this period included the use of electricity as the main source of energy in manufacturing, the emergence of assembly lines, the development of mass production and standardisation of products, the expansion of transport infrastructure and railway lines. Mass production meant a reduction in production costs and wider availability of products to the population [6]. Large industrial corporations and business models based on large-scale production emerged, laying the foundations for modern consumer capitalism [9].

The third Industrial Revolution, referred to as Industry 3.0, represented the advent of manufacturing automation and the use of electronics. The main attributes of this phase of industrial development were the introduction of computer numerical controlled machines (CNC machines), the use of programmable logic controllers (PLCs), the beginnings of robotization of manufacturing, the digitalization of processes and the interconnection of manufacturing with information systems [10]. Industry 3.0 has enabled more flexible production, reduction of manual interventions and automation of repetitive activities. Human work began to move into areas that required expert knowledges, creative thinking and decision making. This phase was also a preparation for the full digitalization of manufacturing processes [11].

The fourth industrial revolution, also known as Industry 4.0, represents the current phase of technological development in which manufacturing systems and processes are fully digitalized and interconnected through technologies such as the Internet of Things (IoT), artificial intelligence (AI), machine learning (ML), big data (Big Data), blockchain and cloud computing. The characteristic attributes of Industry 4.0 include Smart Factories, interconnection of devices and machines using IoT, Digital Twins, collaborative robots, use of AI and machine learning for predictive maintenance, manufacturing optimization and autonomous decision making, blockchain, additive manufacturing [4,12].

Industry 4.0 is not only changing the industrial environment, but also the labour market. Rapid technological progress is transforming employment - traditional manual jobs are replaced by automation, while the demand for professionals in the fields of data analytics, cybersecurity or artificial intelligence is growing [13].

The evolution from Industry 1.0 to Industry 4.0 is a story of constant progress, where each phase has brought new technologies that have fundamentally changed the way we produce, work and live. We are entering an era where artificial intelligence, automation and digitalization are becoming part of everyday life, which requires adaptation not only of companies, but also of educational systems and the whole society to face the challenges and opportunities that these changes bring [11,13].

At the same time, there is already discussion about the arrival of Industry 5.0, which is to focus on the return of the human being to the centre of manufacturing processes and on cooperation between humans and technologies. Industry 5.0 will emphasise personalised manufacturing, ethical responsibility, sustainability and the inclusive development of industrial companies [14].

2.2 Requierements for future competencies

As a result of continuously increasing technological progress and the advent of the fourth industrial revolution, Industry 4.0, not only the manufacturing processes themselves are changing, but also the expectations of the labour market. This is also linked to the growing demand for new competencies, which can be divided into two groups - hard skills, i.e. technological and digital skills, and soft skills, i.e. skills that support a person's ability to function in a dynamic, digital and globalised environment.

According to current research (Raveica et al., 2024; Kowal et al., 2022), the successful individual in the coming years will be those who can effectively combine high-tech skills with mature personality traits and the ability to work in a team, solve problems and adapt to rapidly changing conditions [14,15].

2.2.1 Hard skills – technological and digital competencies

According to Simoes et al. (2020), the growing automation and use of AI does not only mean the loss of some jobs, but also creating new positions that require the ability to interact with digital systems, understand their logic, and the ability to use them to make work more efficient [22]. Technical skills such as working with AI, Big Data, cybersecurity or digital systems are becoming a necessity for effective management of manufacturing processes. Equally important are competencies in logistics, especially the ability to optimize material flows and manage financial flows, which directly affect the efficiency and cost-effectiveness of the company. Within the framework of Industry 4.0, completely new jobs are being created and at the same time existing jobs are being transformed. In the future, companies will require employees to master a wide range of specific skills such as [4,5,9,15]:

- programming and automation,
- Big Data analysis,
- artificial intelligence (AI) and machine learning (ML),
- internet of things (IoT),
- additive manufacturing (3D print),
- blockchain and cybersecurity,
- simulations and digital twins,
- digital skills (ability to effectively use office applications and cloud services, data management and security, working with remote teams).

2.2.2 Soft skills

For all the technological advances of Industry 4.0, the role of the human being as a leader, team player and innovator remains crucial. That's why soft skills will always be an important success factor. Important soft skills include [12,16-18]:

- critical and analytical thinking,
- problem solving,
- teamwork,
- creativity and innovative thinking,
- flexibility,
- digital literacy and digital ethics,
- communication skills,
- emotional intelligence,
- leadership and motivation,
- time management and ability to cope with stress.

According to authors Hernandez-de-Menendez (2020) and Cretu (2025), the most successful employees and managers will be those who can combine highly technical skills with excellent soft skills. Modern companies will appreciate flexibility, lifelong learning, adaptability and openness to change as highly as the ability to handle the most advanced technologies [5,8].

2.3 Adaptability of employees and willigness to learn

In an Industry 4.0 environment where technological change is constantly occurring, adaptability and a willingness to continuously learn is one of the most essential competencies of the future. While technological innovations are evolving at an exponential rate, jobs are transforming and new professions are often emerging faster than education systems can respond to new labour market requirements. According to research by Deloitte and McKinsey, up to 50% of employees will need to be retrained or upskilled by 2030 [15].

Adaptability means the ability to respond flexibly to changes in the environment, whether technological, organisational or cultural. In practice, it is the ability to [19]:

- adopt new ways of working and adapt quickly to new processes,
- react promptly to unexpected situations,
- deal with unpredictable changes in projects, supply chains or markets,
- be open to job or project rotation.

Employees who are adaptable show higher resilience to stress and are able to embrace change as a challenge rather than a threat. Companies appreciate such qualities, especially because they can handle difficult times and become a factor that moves the company forward at the same time. Employee adaptability is key not only in production but also in the management of logistics processes, which are being fundamentally transformed by digitalization and automation [14,20].

2.3.1 Adaptability of employees in the conditions of Industry 4.0

Constantly adapting to new software solutions that change faster than standards can catch up [4]. Flexibility to move to new manufacturing processes (e.g. from traditional manufacturing to additive manufacturing or fully automated lines), as stated by Hernandez-de-Menendez (2020) it is the combination of simulation technologies, digital twins and automation that requires adaptability [5], the ability to collaborate with AI systems and understand their recommendations [8]. Willingness to change established routines and processes if they are inefficient, as Kubišová (2022) points out, where companies in Slovakia reported the need to change

experienced processes in connection with the implementation of Industry 4.0 [12].

2.3.2 Adaptability in multicultural environment

In the Industry 4.0 environment, not only technology, but also the method of work organisation and collaboration are globalised. The ability to adapt to a multicultural environment and to work effectively with colleagues from different countries is becoming one of the key skills of the future. This flexibility includes [8,12,14,16]:

- Sensitivity to cultural differences - employees who can understand and respect different cultural customs are more valuable in companies because they can work more effectively in international teams.
- Ability to collaborate with teams in other time zones - working on international projects requires the ability to be time flexible and communicate across digital platforms across countries.
- Openness to other communication styles and differences of opinion - successful employees are those who can handle different approaches to problem solving and can communicate with foreign partners without conflict.
- Accepting feedback from other cultural contexts - the ability to accept other forms of criticism and positive feedback is key to personal growth and working in a multicultural environment.

2.3.3 Lifelong learning

Industry 4.0 gives importance to the concept of lifelong learning. This means that learning is no longer just a matter of formal study, but a continuous process. The main signs of a willingness to learn are [4,5,12,21]:

- active search for courses, seminars, webinars,
- regular updating of knowledge in the areas of new technologies (AI, IoT, blockchain, cybersecurity),
- ability to learn new digital tools and work with new platforms,
- openness to interact with experienced colleagues and ability to accept feedback.

According to the results of a study published in the journal Sustainability (Raveica et al., 2024), it was those students and employees who showed a high willingness to continuously learn who performed better in the labour market, obtained innovative assignments and were promoted more quickly to leadership positions [14].

Adaptability and willingness to continuous learning are key prerequisites for professional success in the Industry 4.0 environment. Flexibility, the ability to react quickly to change, the willingness to adopt new technologies and continuous learning are becoming mandatory equipment for every employee. In the future, companies will prefer employees who can „keep up with the future“ and see learning as an integral part of a career [8,14,15].

The Fourth Industrial Revolution represents a radical transformation in the way manufacturing processes, the company and society as a whole operate. Digitalization, automation, the Internet of Things, artificial intelligence, big data and other advanced technologies are significantly changing not only manufacturing itself, but also the labour market, education and the requirements for future workforce competencies. Industry 4.0 is therefore not only a technological phenomenon, but also an opportunity to create a more efficient, safer and sustainable economic system. The key to success will be the ability to combine innovative technologies with quality human work, creative thinking and a continuous drive for improvement [8,15].

3 Methodology

In order to find a solution and at the same time to answer the stated aim of the paper, a survey was realized in industrial companies in the period 9/2024 - 11/2024. The survey involved medium and large companies in the field of engineering, whose more specific focus was the automotive industry and broad suppliers for the automotive industry. There were 16 companies that participated in the data collection and all of them are located in Slovakia.

Industrial companies were asked to provide data from competency profiles at the level of operational management - focus on the shift leader position. This position was deliberately chosen because top management does not come into direct contact with automation and new technologies to the extent that they need to be required to have the competencies to work with them. The operational management level uses the most technical competencies, and it is also the lowest level of management, so they are also required to have competencies that will help them to effectively manage the team and lead the employees to achieve the goals, whether of the company or of the individuals.

Small companies were left out of the survey and data collection because jobs are cumulated in them and the implementation of Industry 4.0 is not of significant importance for them due to the volume of production and also in terms of the financial intensity of the measures.

From the collected data on competency profiles, a table was created in which the competencies are listed and ranked based on their frequency of occurrence. There are 39 competencies in the initial table (Table 1). From the table thus created, a further frequency analysis can be carried out, where a criterion has been set that competences with a frequency of occurrence of less than 25%, representing values of 3 – 1, will be removed from the table, as these competencies are not considered to be significant due to their low occurrence. As a result, we are left with 28 competencies for further analysis.

Table 1 Collected data from industrial companies

competencies/skills	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	frequency
production/project management	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	16
knowledge OSH, FP, PPE	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	15
leadership	X	X	X	X	X		X	X	X	X	X		X	X	X	X	14
human resource management	X		X	X	X	X	X		X	X	X	X	X		X	X	13
communication / presentation skills		X	X		X		X	X	X		X	X	X	X	X	X	12
management planning		X	X	X	X	X	X	X		X			X	X	X	X	12
production and technical skills		X	X	X	X	X		X		X		X	X	X	X	X	12
goal orientation	X	X	X			X		X	X	X	X	X	X			X	11
Lean management	X		X	X		X			X	X	X	X	X	X	X		11
knowledge of MS Office	X	X	X				X		X		X		X	X	X	X	10
results orientation	X	X	X	X		X		X		X			X		X	X	10
organization		X	X	X	X		X	X	X		X	X				X	10
teamwork		X	X	X	X	X		X	X		X					X	9
employee motivation		X	X		X	X	X				X		X		X	X	9
knowledge of standards		X	X	X				X	X	X	X		X	X			9
employee development		X		X		X		X	X			X			X	X	8
responsibility					X		X	X	X				X	X	X	X	8
knowledge of P.I.S. (e.g. SAP)	X				X	X	X					X	X			X	7
problem-solving skills		X			X			X			X		X		X	X	7
sustainability orientation		X	X	X							X	X	X				6
flexibility			X		X				X	X	X					X	6
inovativness		X										X	X	X	X		5
creativity and imagination		X	X									X	X			X	5
language skills (AJ - B2)		X	X								X		X	X			5
controling						X	X		X		X				X		5
independence		X			X				X							X	4
analytic thinking			X				X			X				X			4
reporting												X		X	X	X	4
customer orientation		X											X	X			3
resistance to stress		X	X												X		3
technical thinking							X			X				X			3
openness to change		X												X			2
self-education and self-development		X									X						2
strategic thinking			X											X			2
knowledge of BIS	X																1
agile thinking		X															1
knowledge of ITC system		X															1
knowledge of CSR			X														1
assertivity					X												1

After the evaluation of the data, in the next step, the AHP (Analytical Hierarchy Process) method was implemented through Expert Choice software, which allowed us to evaluate and determine the most frequently required competencies from managers operating in Industry 4.0 conditions in an exact way. For easier work and better clarity, these competencies were divided into three groups, namely: managerial, technical and personal competencies. The criteria on the basis of which the competencies were assessed are: financial requirements for implementation, qualification requirements for employees, technical requirements for implementation and time requirements for implementation.

4 Results and discussion

To use the AHP method, we first need to create a hierarchical structure. We have entered the objective (Selection of competencies for the application of Industry 4.0 techniques) and the criteria (see above) into the Expert Choice software, to which we have then entered the individual variants (specific competencies). We then proceeded with a pairwise comparison of the individual criteria with respect to the main objective.

Figure 1 shows the hierarchical structure of our decision-making process, but we input three separate models into the Expert Choice software, one for each set of competencies. After pairwise comparing the criteria and determining their order of importance, we also pairwise compared the variants themselves, and thus the individual competencies, with respect to a given criterion. After pairwise comparisons with respect to all four criteria, the Expert Choice software produced a final ranking of the decision-making process for all three groups of competencies.

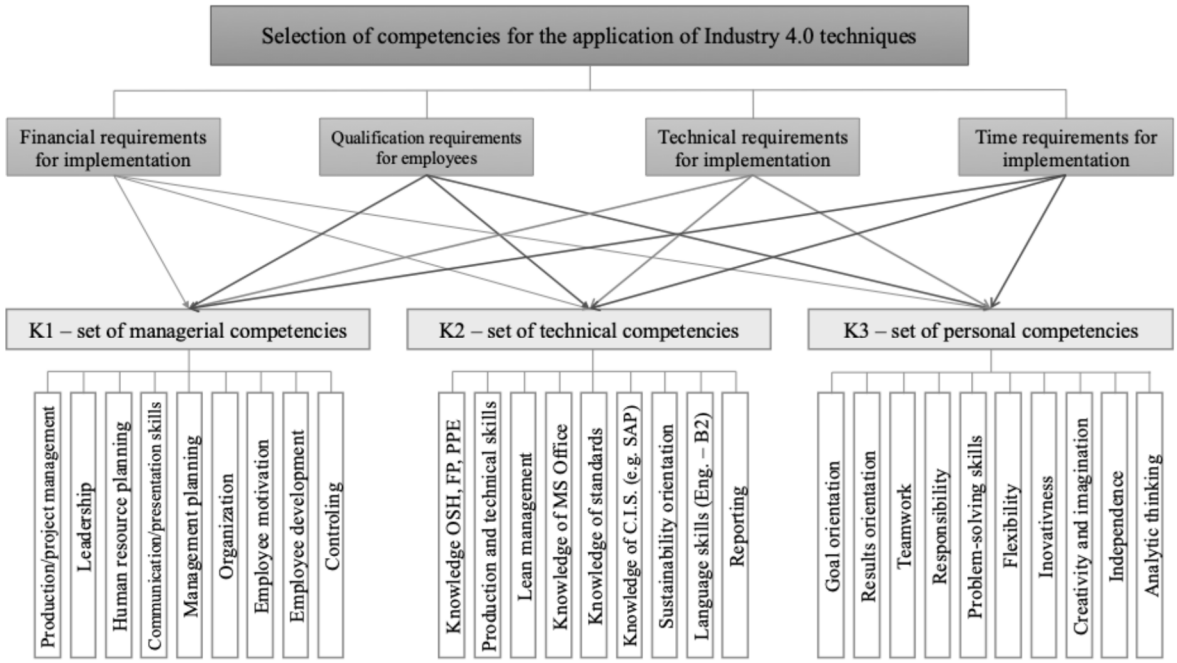

Figure 1 Hierarchical structure of decision-making process

Based on the information and knowledge gathered so far, the competency profile of a manager should generally consist of 10 to 12 competencies. With fewer competencies, it would be too simplistic and might not cover everything that is required of an employee in a managerial position. On the other hand, if there are more competencies, the profile would be too broad and difficult to apply in practice. As in our model, competencies in competency profiles tend to be divided into several sets (managerial, technical/professional, personal and interpersonal), their quantity and structure varying with the company's requirements, objectives as well as with the level of management for which the competency profile is created.

By realizing the AHP method in assessing the importance of competencies, we can in the result select the relatively most important competencies for operational managers to be able to lead teams and manage manufacturing processes effectively. In our decision-making process, there were 28 competencies identified by industrial companies as required, divided into three sets in approximately equal numbers. Based on knowledge, information and experience, we can argue that a competency profile should be made up of between 10 and 12 competencies, so we selected the four competencies with the highest scores from each competency set. In the set of personal competencies we added a fifth competency for the relevance of the results, because the base set in this case was 10 and not 9 as in the other two competency sets.

The final draft of the competency profile of the operational manager based on the results of the AHP method will therefore consist of the following competencies:

a) Managerial competencies:
1. Production / project management
2. Employee development
3. Management planning
4. Leadership

b) Technical competencies:
1. Lean management
2. Knowledge of C.I.S. (e. g. SAP)
3. Language skills (Eng. – B2)
4. Knowledge of standards

c) Personal competencies:
1. Analytic thinking
2. Problem-solving skills
3. Innovativeness
4. Creativity and imagination
5. Teamwork

According to the latest Future of Jobs Report 2025 [23], the biggest barrier to the transformation of companies is the skills gap and missing competencies in the labour market, according to 63% of respondents. This is an even higher result than in 2023, which means that companies are increasingly aware that without the necessary competencies of their employees they will not be able to undergo a full transformation and their position in the market will not be competitive [23].

The Future of Jobs Report 2025 lists the competencies that are on the rise between 2025 and 2030 and companies are recognising their importance. To compare and possibly identify the differences between the competencies selected by us using the AHP method and the competencies selected in the global report, the following table is used.

Table 2 Selected required competencies from Expert Choice vs. „Skills on the rise 2025 – 2030" from FOJR

Selected required competencies	***"Skills on the rise 2025 – 2030"***	***Net increase***	***Associated competencies***
Production / project management			Resilience, flexibility and agility
Employee development	Teaching and mentoring Curiosity and lifelong learning	30 61	Talent management
Management planning	Resource management and operations	24	
Leadership	Leadership and social influence	58	
Lean Management	Systems thinking	51	Technological literacy
Knowledge of C.I.S. (e.g. SAP)	Networks and cybersecurity	70	AI and Big Data
Language skills (Eng. – B2)	Multi-lingualism	16	
Knowledge of standards	Quality control	20	Environmental stewardship
Analytic thinking	Analytical thinking	55	
Problem-solving skills			
Innovativeness			Design and user experience
Creativity and imagination	Creative thinking	66	
Teamwork			Motivation and self-awareness Empathy and active listening

The first column of Table 2 shows the competencies that were selected based on the results of the AHP method. The second column shows the competencies from the Future of Jobs Report survey [23], which we matched based on their similarity to the competencies in the first column. The "Net increase" column is the difference between those companies that consider a given competency to be increasing and those that consider a competency to be decreasing over the specified period. In the last column are the associated competencies, so they are not exactly the same competencies as in the first column, but there is some affinity between them, and it can be argued that managers also need to have these competencies to perform effectively and reliably in their jobs.

On the basis of Table 2, where we compared our AHP method for selection of competencies for the application of Industry 4.0 techniques and the competencies identified in the Future of Jobs Report 2025 [23], we can confirm that the competencies that emerged as a result of our decision-making process are not only necessary for industrial companies operating in Slovakia, but are globally demanded competencies. However, it is not enough to identify competencies and find employees who possess them. Employee competencies need to be continuously developed, care needs to be taken to retrain employees, as well as to increase their qualifications and to place great emphasis on lifelong learning, which is essential for maintaining the competitiveness of both individuals and industrial companies in a dynamically changing environment. Companies must therefore strive to match the competencies offered by their employees with evolving requirements and reflect the needs of new technologies.

Technological progress, the transformation of industrial companies into companies operating in the Industry 4.0 era (in Slovakia, in the world we can already talk about Industry 5.0), the transition to a more environmentally friendly way of manufacturing are the driving force for changes in the labour market, which changes jobs and at the same time the requirements for employee competencies. AI and information processing technologies will have the biggest impact on companies, as stated by 86% of the companies participating in the survey [23].

Based on the survey of the Intelligent Industry Association - Industry4UM on the level of implementation of Industry 4.0 in industrial companies, only a third of companies are currently applying their digitalization strategy. The implementation is most limited by financial resources, which are mainly affecting small and medium-sized companies and companies with Slovak ownership. Based on the survey results, we know that the implementation of Industry 4.0 fails most on the financial side, with up to 60% of companies identifying financial constraints as an obstacle. Lack of digitalization skills of employees was identified by 39% of companies as a limiting factor. The skills gap is most pronounced in the areas of artificial intelligence, programming and data analytics, suggesting a need for education and re-skilling of employees, as well as improved hands-on learning for better implementation of Industry 4.0 or Industry X.0 [24].

5 Conclusions

Changes in labour market competencies in the context of the implementation and application of Industry 4.0 techniques are challenging and require adaptation on the part of both companies and employees. The research results showed that the key competencies of managers at the operational level are technical skills, but also soft competencies such as analytical thinking, creativity and teamwork. The AHP method allowed us to identify the most important competencies for successful operation in Industry 4.0 conditions. The competencies that resulted from the AHP method (see Table 2) are not only necessary for industrial companies in Slovakia, but are globally demanded competencies. However, in a constantly changing environment, where the degree of automation and digitalization is rapidly increasing and new

technologies are entering the market, it is important to update the competency profiles and reflect the requirements of technological progress in them. The level of individual competencies may also vary, which emphasises the need for continuous learning and development not only of new competencies but also of those already acquired by employees.

The main contribution of this paper is the identification of a specific set of competencies that operational manager should have in order to be able to effectively manage production and human resources in Industry 4.0 conditions. The results from the AHP method can be valuable for industrial companies in planning training programs, creating competency profiles, but also in developing human resource strategies that correspond to the requirements of digitalization. Companies have to face challenges in implementation such as financial constraints and lack of competences and digital skills of their employees. In order to maintain their market position and remain competitive, companies will need to invest in retraining, upskilling and lifelong learning for their employees. At the same time, it will also be necessary to actively adapt competence profiles to the changing labour market situation.

But the study also has limitations, as the data were collected exclusively from industrial companies operating in Slovakia, mainly in the engineering and automotive industries. Therefore, future research could be extended to other industries, other regions (countries) and examine the implementation of new concepts such as Industry 5.0.

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