Human-Machine Co-Working for Socially Sustainable Manufacturing in Industry 4.0

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Abstract: Human-machine cooperation is an activity used to maximize job openness for all workers by removing barriers of languages, disability, age, gender barriers and maximizing employee well-being and motivation. The diverse technologies providing physical and cognitive assistance should facilitate attractiveness and facilitate employment, and thus social sustainability within the production section. The main goal of this paper is to analyze the current state of human-machine cooperation and identify the requirements for future human-machine cooperation for socially sustainable manufacturing in Industry 4.0.

Keywords: human-machine cooperation; Industry 4.0; employment; production processes; social sustainability

Introduction

The world has witnessed three industrial revolutions since the end of the eighteenth century, which have brought major leaps in the efficiency and productivity of industrial activities. The 4th Industrial Revolution and Digitization Society are currently taking place on a global scale. We encounter elements of digitization not only in industrial enterprises and industry as such, but they can be found in everyday life as well.

While the first and second industrial revolutions were characterized by mechanization based on the invention of the steam engine and electrification of production processes, the third industrial revolution was defined by more progressive automation of processes to production [1].

A characteristic element of the fourth industrial revolution is the digitization of all systems within the organization and their interconnection into one whole, such a revolution can be referred to as Industry 4.0. Industry 4.0 is characterized by interactions and communication between industrial equipment (machines) and cyberphysical systems for real-time operations management, the Internet of Things, artificial intelligence, robotics, cybersecurity, and other elements and technologies that contribute to technical sophistication, increased competitiveness, and production automation [2, 3].

The main idea of industrial transformation is to increase the competitiveness of enterprises, through increasing resource efficiency and productivity [4]. Quality of work, quality of processes, overall quality, and product safety are important for maintaining and improving the competitiveness of companies. The issue of quality in every industry has become a parameter of a company's survival in a turbulent competitive market. In addition to the quality of products and services, the success of companies also depends on the performance of the processes taking place in the system [5, 6].

The article is structured as follows: section 1 provides the theoretical background characterizing sustainable production, followed by human-machine collaboration in industrial practice. Section 2 describes the empirical data on the issue under study, obtained through a survey, then the research questions and hypotheses are stated. In Section 3, the research questions and hypotheses are evaluated and interpreted. Section 4 provides a discussion of the paper's topic, followed by a conclusion, including a suggestion of possible directions for future research.

1 Theoretical Background

One of the goals of the implementation of Industry 4.0 is to increase the professional knowledge and qualifications of people, and thus increase the well-being of employees under the guarantee of sustainable jobs. In Industrial Revolution 4.0, there is no competitive battle between workers and machinery. Industry 4.0 offers opportunities for more efficient use of human potential in cooperation with machines [3].

The EU's population is aging and the EU's working-age population will fall by 1/3 by 2050 [7]. In addition to this change in society, new working styles, working from home and working with robots are becoming popular, and societal and working lives are being transformed [8].

1.1 Socially Sustainable Production

Social sustainability was emphasized only after the Rio Conference in 1992. The United Nations Conference on Environment and Development (UNCED) sets out in its Agenda 21 human and social issues and their impact on sustainability. The first part of Agenda 21 emphasizes the importance of combating poverty, protecting and promoting human health, and creating an impetus for sustainable human settlements, a social and economic dimension [9]. Researchers also define social sustainability as *"a code of conduct for human survival and growth"* and *"must be achieved in a mutually accessible and prudent manner"* [10]. Social responsibility can be defined as *"the obligation of a company to use its resources in a way that is beneficial to society, through engaged participation as a member of society, consideration of society as a whole, and improving the well-being of society as a whole without regard to direct profits"* [11].

This concept of social sustainability can be extended to include the management of social resources, including people's skills and abilities, relationships, and social values. The United Nations Framework for Sustainable Development (UNDSD) classifies the dimensions of sustainable development and includes the social and economic environment. In the social dimension, the identified indicators are equality, education, health, housing, safety, and population. Social Sustainability (SU) is grouped into three categories (SU development, SU bridging, and SU maintenance) [12, 13].

It is these three categories of social sustainability that speak of social sustainability as an approach that helps humanity address social issues such as poverty, equality, education, wages, human rights, and diversity. However, social problems in industrialized economies differ from emerging economies due to their very different social standards. Social sustainability seems to be more difficult to accept and understand in many enterprises. Measuring the impact of social responsibility is a more challenging task for organizations, especially small and medium-sized enterprises. The concept of corporate social responsibility includes activities related to the social dimension of sustainability, but can have different meanings depending on the context and interpretation. In companies, we often discuss the concept of sustainable production [14, 15].

In addition to research, the concept of sustainable production has also moved to small and medium-sized enterprises, especially in industrial production. Sustainability of production is based on three areas: economic, environmental, and social. Sustainable production can be defined as the production of products in a way that minimizes environmental impacts and takes on the social responsibility of employees, the community, and consumers throughout the product life cycle and achieves positive economic results. The results of aligning organizations with the goals of socially sustainable production are clear. Decent jobs help keep employees at work, occupational safety and health care reduce illness and absence, and continuous employee training provides them with higher quality and productivity. At present, the sustainability of production is most closely linked to the environment, for example, companies in the automotive industry. The aim is to reduce emissions in production through which it is possible to reduce the environmental impact by 45% per vehicle produced. Automotive companies such as Volkswagen, Tesla, etc. came up with a new concept for the production of electric cars. The mentioned examples of sustainable production with respect to the environment are related to human-machine cooperation. The reason for this cooperation is and will be new technologies and machines and at the same time a declining demographic curve. Man-machine cooperation is expected to contribute to reducing emissions, greenhouse gases, and industrial waste. Humanity is entering a period where the industry's intention is to affect the climate and the environment as little as possible. However, we cannot forget the man and his stable working conditions and environment at the same time, so a man in the production environment is complemented by a robot and two human-machine entities work together [15, 16, 17].

1.2 Man-Machine Cooperation

In order to prepare for labor shortages in the near future, it is necessary to take into account the fact that the working style of employees will change. Humans will work in coexistence with intelligent systems and robots. The production system in industrial enterprises will be fully automated, using various technologies and machines. The focus of job fear has shifted to automation, where people are replaced by machines. So we should discuss partnerships and man-machine cooperation in the workplace. Paradigms, between human-machine cooperation, should move from taking on a role to thinking together, learning together, and working together. The vision for the future is that machines will increasingly work and behave like humans. This means that creativity, intuition, and ethics can be common to humans as well as to machines in certain elements. It is assumed that human-machine algorithms will be developed and human-machine relationships will be managed by experts. People will have to trust the decisionmaking of autonomous machines. Relationships between humans and machines will require new industrial psychology [18].

One of the central characteristics of Industry 4.0 activities is the integration of two entities, the machine, modern technological progress and people (employees) [19]. It follows that future competitiveness should not only be ensured by superiority in productivity based on automation, but especially in the offer of added value to customers. For this reason, meaningful integration of the strengths of both the human and machine entities will increase production flexibility [20]. Successful cooperation and interaction of people with different machines (innovative technological hardware and software components) will be of great importance in various areas of industrial production (automotive industry, engineering industry, electrical industry, metallurgy) and also in the field of agricultural production.

In order to achieve a symbiosis of man and machine [21, 22]. The Industrial Revolution, in which industry, as well as society as a whole, finds itself, is transforming the design, engineering, production, operation, and service of products and production systems [23].

As stated by Krupitzer in his research [22], in which he analyzes the current state of human-machine interaction in Industry 4.0. Initial research and scientific efforts in the study focused on fully manageable systems. Over time, research has focused on adaptive mechanisms. This has led to the requirement to establish human-machine elements and to work together. In a complex the man-machine system can no longer be considered individual isolated units, but as a dynamic team working together on a common task. It is natural that even if some of the jobs of operators in production remain, some will not survive as we know them today. New profiles of workers with specific skills will be needed immediately, where manual work will be reduced in favor of cognitive and analytical skills and the way of working will be fundamentally changed. Information technology and work activities such as data analysis come to the front. According to the estimates of the US statistical office, there is talk of 1.37 million people in the US who will be retrained for the so-called "New viable" professions. Professions that do not currently exist at all, but will require skills and abilities in the field, such as (analysis of big data of users and entities, internet of things, markets with applications and web, virtual reality, creators of computer systems, cooperation with stationary robots, humanoid robots, etc.). These positions will include software developers, database administrators, computer systems engineers, and computer and information research scientists [15, 24].

Advanced modern digital and industrial technologies will help people stay in, return to, or join modern manufacturing companies and workgroups. Thanks to technological developments, such as new connectivity options and intelligent technologies between components, machines and humans, industrial production systems are increasingly evolving towards the idea of leaner, and more integrated production, real-time data monitoring, evaluation, and adaptation to production conditions [25].

The new work environment, based on the ideas of cyberphysical factories and the digital twin, will directly affect the operator, the nature of the work, and create new working connections between people and machines in the workplace, but also between the digital and physical environments. The future of companies through transformation to Smart Factories will require a new design and engineering philosophy for production systems focused on socio-technological transformation. Automation, robotics, and other modern technologies are considered elements that could further improve and expand human capabilities [21, 26]. The expansion and improvement of human capabilities in Smart Factory will be controlled by the Operator 4.0 model, where the operator will be understood as an "intelligent and skilled operator" performing its work not only with robots but also with intelligent machines using cyberphysical systems to achieve advanced human-machine interaction and achieving a man-machine working symbiosis in automation. This understanding of Operator 4.0 is based on the assumptions of the industrial production of the future, which will require the analysis of big data of users and entities, the Internet of Things application, virtual reality cooperation with stationary robots and humanoid robots. The result will be the creation and development of new skills and knowledge of operators. In the future, the operator will be understood in a different sense than today. The operator will need to be qualified and professionally focused on data analysis, working with information systems, cloud solutions, and the Internet of Things. It is very likely that human-machine cooperation will take place using a computer [27].

A study [28] describes simultaneous localization and mapping (SLAM) technology. This technology is used in robots and robotic devices that evaluate and scan space in real-time. Using similar technology, new robots will be created in the industrial environment, which will be able to relieve people in the production process. Hancock [29] expressed the idea of human-machine interactions with respect to social sustainability. According to him, machines and automation should adapt to the cognitive and physical requirements of people in a dynamic way. In such a sense, adaptive automation aims to optimize man-machine cooperation and efficiently distribute man-machine work in a production system. The idea of adaptive automation will help increase the efficiency of the production system in a sustainable way, man and machine will achieve symbiosis in the production system and achieve production goals. The main goal of this adaptive automation paradigm is to achieve efficient production efficiency, prevent errors, and thus increase quality and eliminate forms of waste and improve the mental and physical burden on people. Everything is focused on the fact that people should never be subordinated to machines and automation, but on the contrary, machines, and automation must be helpful to people. According to Hancock and others, in order to achieve the sustainable development of human society, that is, the symbiosis between man and machine, automation is needed through the use of intelligent automation systems that will enable man's goals and plans to be met. Romero presented the involvement of "Enterprise Architecture (EA)", which represents a set of knowledge between man-machine cooperation. EA considers the socio-technological aspects of systems, combines management and engineering practices, highlights key requirements, principles, and models, includes people, business information, and technology processes, and describes the company's future position [25, 29, 30].

Innovation, based on the human-machine cooperation paradigm, benefits primarily from the advent of new technologies and ideas in the industrial environment. The advantage of open systematic innovation is primarily the use of machine intelligence on complex networks in the environment and the ability to quickly select those innovative technologies with the greatest potential. Technologies based on the ideas of a socially sustainable business environment, technologies that make work easier for people, minimize environmental pollution, and improve the economic environment of the company. Closed innovation in the business environment will lead to a well-modeled search for business opportunities that can benefit the whole community. Patented systematic innovation will benefit from the man-machine function, joint innovation at a competitive advantage through rapid decision making, the creation of new markets, and the alignment of products and services with market dynamics. The technologies needed for machine intelligence are already available. The use of these technologies can have a positive impact on people's behavior and business development. The needs of today's market, as expressed by today's and tomorrow's consumers, call for advanced innovation processes that are fast and lead to customer-tailored products and services that are efficient. In this complex environment, intelligent machines will play an important role in the future. The impact of emerging events that have the potential to change the world of work and life will continue to evolve exponentially, resulting in the constant development of innovation, both inside and outside the business environment [31].

For Industry 4.0, costs and sustainable development are key aspects to consider when implementing new technologies. Cyber-physical systems, cybersecurity, blockchain, and additive manufacturing play an important role in the redistributed production model that promotes social sustainability. Technologies such as digital twins and Big Data will enable better data analysis in cooperation in the context of man and machine [32, 33, 34].

Lagashev [35] says in his research that cloud computing is currently one of the most widely used technical solutions for data processing and interconnection of this data within machines. And in the presented article he discusses the issue of a cloud server, which also deals with human-machine cooperation.

1.1.1 Man-Machine Cooperation in Industrial Practice

German industrial corporations in the automotive and engineering industries are among the leaders in Europe and in the world. Companies are technologically advanced, they are introducing new technologies and they have the financial means to implement new elements of the most modern technologies.

When the government of the Federal Republic of Germany came to the public in 2011 with the term Industry 4.0, all German corporations and companies began to implement elements of Industry 4.0. Industry 4.0 was created to improve the economic and industrial environment in Germany and Europe. The issue of the aging population in the EU and the labor shortage in the industry are also significant. As a result, technologies and machines have begun to be introduced into manufacturing companies and industries that can replace people or make work easier. This Industry 4.0 idea is not about removing people from production. Rather, it should motivate people to make their work easier, one of these paradigms being man-machine cooperation.

2 Materials and Methods

Empirical data on the researched issue were obtained using a scientific questionnaire. The questionnaire contained 37 closed questions, the first part was focused on finding out the identification and demographic characteristics of respondents, and in the second part we focused on the following four questions:

RQ1: Do you feel threatened by the introduction of new technologies in your organization?

RQ2: Do you currently consider your employer's social behavior (employee care) to be socially responsible?

RQ3: In what areas do you consider your employer's behavior to be socially responsible?

RQ4: Which skills do you consider most important in terms of digitization and job automation (0 don't know; 1 least important to 5 most important)?

Based on the research questions and for the purpose of the paper, the following research hypotheses were defined:

Hypothesis 1: In the fear of employment by introducing new technologies, there is a significant difference between employees of different positions.

Hypothesis 2: There is a significant difference in skills needed with regard to digitization and automation between employees in different job positions.

It was 556 respondents who filled in the questionnaire. Respondents answered the questions in the questionnaire as representatives for the company, not as individuals in terms of their employment status. Due to the thematic focus of our contribution, we focused on companies operating in the industrial sector with small (10 to 49 employees), medium (50 to 249 employees), and large (250 and more employees). We have excluded micro-enterprises (1 to 9 employees) from our research because the topic of human-machine cooperation will be implemented significantly in small, medium, and large enterprises. After filtering out the variables, we looked at a research sample of 322 respondents.

Data processing was performed using Microsoft Excel and IBM SPSS Statistics 28.0.0.0. The interpretation of the data was processed through statistical methods, such as histograms, pie charts, and chart analyses. Statistical quadratic tests and ANOVA were used to test the relationships between dependent and independent variables.

A deeper distribution of respondents operating in individual sectors of industrial production can be found in Figure 1. We focused mainly on the 4 largest industrial sectors in Slovakia.

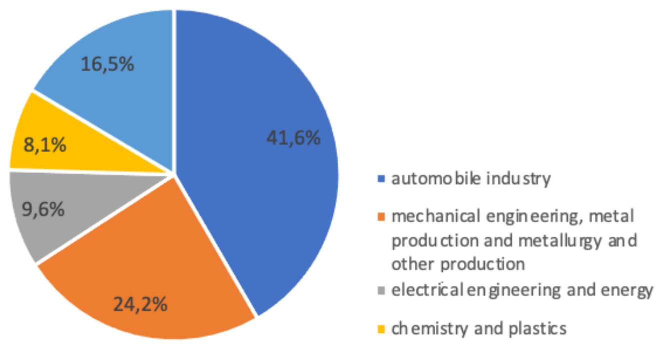

Figure 1
Distribution of respondents operating in individual sectors of industrial production

The distribution of respondents according to the size of the company according to the number of employees in which they work is shown in the pie chart in Figure 2. The graph shows that the largest part of respondents come from large companies (72.4%). It is in large companies that a massive integration of human-machine entities is expected. The rest of the respondents come from medium-sized enterprises (19.9%) and small enterprises (7.8%). In another question, we examined the representation of respondents depending on gender and job position. Based on these data, we can conclude that 64.3% of respondents were men, and 35.7% were women. Part of socially sustainable production is balancing gender equality across the organization, and based on the results of the analysis, the authors state that the current distribution is not in line with the trend of sustainable development, which may result in fewer inaccuracies in predictions for future human-machine cooperation with regard to gender diversity.

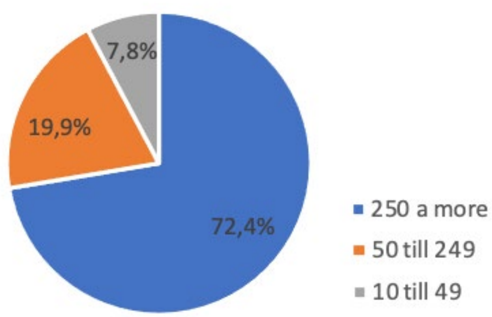

Figure 2
Representation of the relative number of respondents and the size of the company according to the number of employees

The distribution of respondents by job position is shown in Table 1. The term employee specialist is understood as an employee who may or may not be in a managerial position, but in terms of his job description is key to the management of production. Further, a 'production worker' is not a person who carries out operational activities directly in production, but a person who manages operational activities (i.e. the lowest level of management within the relevant organisational management structure, e.g. a teamleader). For this reason, we consider these views to be comparable.

Table 1
Distribution of respondents by job position and men/woman

Work position	**Overall**		**Men**		**Women**	
	Absolute frequency	Relative frequency	Absolute frequency	Relative frequency	Absolute frequency	Relative frequency
employee specialist	102	31.7%	71	34.3%	31	27.0%
administrative staff member	80	24.8%	31	15.0%	49	42.6%
production worker	61	18.9%	42	20.3%	19	16.5%
management position	59	18.3%	46	22.2%	13	11.3%
other	20	6.2%	17	8.2%	3	2.6%

3 Research Results

In the following section, the individual research questions are evaluated and interpreted, as well as the research hypotheses that the authors considered. Due to the insignificant number of respondents who indicated other in the job position, these responses were excluded when examining the research questions and hypotheses as the results would not have relevant predictive power.

Research Question 1: **Do you feel threatened by the introduction of new technologies in your organization?**

We used basic descriptive statistics to evaluate the research question. In this research question, we examined how employees feel threatened by the introduction of new Industry 4.0 technologies. The significance of the threat in this research question is defined by the future expected degree of threat to their current job position. The obtained results are shown in Table 2. Based on the above results, it can be stated that 93 respondents (31%) state that their position is not in danger or employees do not feel threatened by the implementation of new technologies and 82 respondents (27%) say, "no, I assume that this will have a significant positive effect on my work". The fact that 58% of all respondents have a positive attitude towards the introduction of new technologies in companies is a very important factor for the future of the business environment and the competitiveness of Slovak companies. In such work environments, human-machine cooperation will be implemented much better and more smoothly. From a job standpoint, it is worth mentioning the words "yes, I am worried about my job" (15%) and "yes, I am afraid that this will have a significant negative impact on my job" (10%) by production workers. From the results, we can conclude that the introduction of new technologies into companies from the perspective of employees can be perceived as a positive feature of the 4th Industrial Revolution, which focused on a high degree of automation and direct man-machine cooperation. The fourth industrial revolution, focusing on human-machine cooperation in the context of socially sustainable production, does not aim to remove employees from companies, but on the contrary to simplify their work or provide them with new jobs with an adequate retraining program.

Table 2
The feeling of endangering employees by introducing new technologies in the company

	employee specialist		administrative staff member		production worker		management position		overall	
	Abs. freq.	Rel. freq.	Abs. freq.	Rel. freq.	Abs. freq.	Rel. freq.	Abs. freq.	Rel. freq.	Abs. freq.	Rel. freq.
yes, I am worried about my place	2	2%	3	4%	9	15%	1	2%	**15**	**5%**
yes, I am afraid it will have a significant negative impact on my work	5	5%	3	4%	6	10%	0	0%	**14**	**5%**
I think it will affect my work to a minimum	14	14%	18	23%	12	20%	7	12%	**51**	**17%**
I do not feel threatened	31	30%	23	29%	17	28%	22	37%	**93**	**31%**
I did not think about it	13	13%	9	11%	8	13%	2	3%	**32**	**11%**
no, I assume that this will have a significant positive effect on my work	34	33%	19	24%	5	8%	24	41%	**82**	**27%**
I am worried about my work for other reasons (e.g. economic consequences of COVID-19)	3	3%	5	6%	4	7%	3	5%	**15**	**5%**
overall	**102**	100%	**80**	100%	**61**	100%	**59**	100%	**302**	**100%**

Hypothesis 1: **In the fear of employment by introducing new technologies, there is a significant difference between employees of different positions.**

Table 3
Results of Hypothesis 1

Chi-Square Tests				
Please indicate which sector you work in:		**Value**	**df**	**Asymptotic Significance (2-sided)**
industrial production	**Pearson Chi-Square**	**48.736**	**18**	**0.000**
	Likelihood Ratio	51.539	18	0.000
	Linear-by-Linear Association	3.407	1	0.065
	N of Valid Cases	302		

The hypothesis was tested based on the job positions from which the possibility of job positions, which have been included in other, was excluded. The results are shown in the Table 3, the hypothesis was verified by Chi-Square Test and the strength of the correlation was determined using Cramer´s V value in the Table 4.

Table 4

Results of Hypothesis 1 Cramer´s V

Symmetric Measures				
Please indicate which sector you work in:			**Value**	**Approximate Significance**
industrial production	Nominal by Nominal	Phi	0.391	0.000
		Cramer's V	**0.226**	0.000
	N of Valid Cases		302	

Significance came out less than 0.05, that is, we reject H0 at 0.05 level of significance and this implies that there are significant differences among the workers in their concern about their job position. According to the value of Cramer's V is 0.226 so the result is that the dependence between the variables is moderately strong.

Research question 2: **Do you currently consider your employer's social behavior (employee care) to be socially responsible?**

In this research question, we examined the opinion of employees on the social area, with which we can connect social sustainability. The results obtained are shown in Table 5 depending on the job position. Based on the above results, it can be stated that a total of 218 respondents (72%) rate the employer's behavior as socially responsible. These results were evaluated depending on the variable job position and from the above results it is worth noting that up to 54 respondents, which is 92%, who work in the management positions evaluate the employer as socially responsible.

Table 5

Socially responsible (socially sustainable) behavior of the employer

	employee specialist		**administrative staff member**		**production worker**		**management position**		**overall**	
	Absolute frequency	**Relative frequency**	**Absolute frequency**	**Relative frequency**	**Absolute frequency**	**Relative frequency**	**Absolute frequency**	**Relative frequency**	**Absolute frequency**	**Relative frequency**
yes	69	68%	62	78%	33	54%	54	92%	**218**	**72%**
do not know	23	23%	15	19%	20	33%	4	7%	**62**	**21%**
no	10	10%	3	4%	8	13%	1	1%	**22**	**7%**
overall	**102**	100%	**80**	100%	**61**	100%	**59**	100%	**322**	**100%**

Research Question 3: **In what areas do you consider your employer's behavior to be socially responsible?**

In the third research question, we examined the opinion of employees on a specific social area in which their employer behaves socially responsibly. The results obtained are shown in Table 6 as absolute and relative numbers depending on the employee's job position. In the given question, the respondents had the opportunity to choose from several answers. Based on the above results, it can be stated that we received a total of 338 responses, of which a maximum of 193 (57%) responses were listed under the option "activities and measures to promote health". Other answers were "work-life balance" answered by 82 (24%) respondents. It was 38 (11%) respondents described “support for disadvantaged employees” and “support for vulnerable communities” was identified by 25 (7%) by respondents as the area that respondents considered least affected by the employer's actions.

Table 6

Areas of social behavior of the employer

	employee specialist		**administrative staff member**		**production worker**		**management position**		**overall**	
	Abs. freq.	**Rel. freq.**	**Abs. freq.**	**Rel. freq.**	**Abs. freq.**	**Rel. freq.**	**Abs. freq.**	**Rel. freq.**	**Abs. freq.**	**Rel. freq.**
activities and health promotion measures	64	62%	54	62%	25	39%	50	60%	**193**	**57%**
support for disadvantage d employees	9	9%	9	10%	9	14%	11	13%	**38**	**11%**
work-life balance	22	21%	21	24%	22	34%	17	20%	**82**	**24%**
support for vulnerable communities	8	8%	3	3%	8	13%	6	7%	**25**	**7%**
overall	**103**	100%	**87**	100%	**64**	100%	**84**	100%	**360**	**100%**

Research questions 2 and 3 are directly related to the socially sustainable area and say what activities employers carry out in order for this social area to develop and be sustainable.

Research question 4: **Which skills do you consider most important in terms of digitization and job automation (0 don't know; 1 least important to 5 most important)?**

Table 7
Ability / skill

	Value	employee specialist		administrative staff member		production worker		management position		overall	
		Abs. freq.	Rel. freq.	Abs. freq.	Rel. freq.	Abs. freq.	Rel. freq.	Abs. freq.	Rel. freq.	Abs. freq.	Rel. freq.
technical (professional) skills	**0**	3	3%	1	1%	3	5%	0	0%	**7**	**2%**
	1	26	25%	16	20%	10	16%	7	12%	**59**	**20%**
	2	7	7%	9	11%	6	10%	4	7%	**26**	**9%**
	3	5	5%	12	15%	9	15%	10	17%	**36**	**12%**
	4	29	28%	17	21%	13	21%	20	34%	**79**	**26%**
	5	32	31%	25	31%	20	33%	18	31%	**95**	**31%**
digital skills	**0**	3	3%	1	1%	2	3%	0	0%	**6**	**2%**
	1	23	23%	14	18%	6	10%	5	8%	**48**	**16%**
	2	11	11%	9	11%	9	15%	9	15%	**38**	**13%**
	3	11	11%	14	18%	12	20%	12	20%	**49**	**16%**
	4	18	18%	12	15%	7	11%	14	24%	**51**	**17%**
	5	36	35%	30	38%	25	41%	19	32%	**110**	**36%**
ability to learn	**0**	3	3%	0	0%	1	2%	0	0%	**4**	**1%**
	1	26	25%	23	29%	10	16%	7	12%	**66**	**22%**
	2	7	7%	3	4%	11	18%	7	12%	**28**	**9%**
	3	9	9%	15	19%	8	13%	13	22%	**45**	**15%**
	4	20	20%	18	23%	14	23%	15	25%	**67**	**22%**
	5	37	36%	21	26%	17	28%	17	29%	**92**	**30%**
flexibility, adaptation	**0**	5	5%	1	1%	2	3%	0	0%	**8**	**3%**
	1	17	17%	15	19%	6	10%	5	8%	**43**	**14%**
	2	13	13%	10	13%	8	13%	11	19%	**42**	**14%**
	3	20	20%	23	29%	19	31%	13	22%	**75**	**25%**
	4	18	18%	17	21%	14	23%	11	19%	**60**	**20%**
	5	29	28%	14	18%	12	20%	19	32%	**75**	**25%**
social (ability to get along with other people)	**0**	5	5%	1	1%	3	5%	0	0%	**9**	**3%**
	1	16	16%	14	18%	7	11%	10	17%	**47**	**16%**
	2	28	27%	20	25%	18	30%	13	22%	**79**	**26%**
	3	27	26%	19	24%	17	28%	21	36%	**84**	**28%**
	4	11	11%	14	18%	9	15%	8	14%	**42**	**14%**
	5	15	15%	12	15%	7	11%	7	12%	**41**	**14%**
overall		**102**	100%	**80**	100%	**61**	100%	**59**	100%	**302**	**100%**

In the last research question, the authors dealt with the abilities or skills that employees consider most important with regard to digitization and job automation. The research question, by its very nature, deals with the future requirements for the ability of employees in human-machine cooperation. In the questionnaire survey, respondents commented on the question on a scale from 0 (I do not know);

1 (least important) to 5 (most important). Respondents had the opportunity to comment on the following skills: technical (professional) skills; communication skills; organization of time within work, and work tasks; ability to manage and make decisions; ability to learn; ability to work under pressure; digital skills; language (foreign languages); social (ability to get along with other people); initiative (entrepreneurship, commitment); flexibility, adaptation; creativity and creativity. As some skills and knowledge do not directly relate to our research area, human-machine cooperation in socially sustainable production, we have decided to select only the following skills/competencies that we consider essential in human-machine cooperation. The skills and competencies are evaluated in Table 7. Overall, the most numerous skills were of a technical (professional) nature and digital skills. It was 110 (36%) respondents rated digital skills as the most important and up to 95 (31%) respondents rated technical (professional) skills as the most important. We assume that the effective synergy between the mentioned digital skills and professional skills will be key in the integration of employees affected by Industry 4.0 technologies in the context of human-machine cooperation.

Hypothesis 2: **There is a significant difference in skills needed with regard to digitization and automation between employees in different job positions.**

The hypothesis was tested based on the job positions. The results are shown in the Table 8, the hypothesis was verified using analysis of variance.

Table 8
Results of Hypothesis 2 - ANOVA

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
technical (professional) skills	Between Groups	4.311	3	1.437	0.630	**0.596**
	Within Groups	663.723	291	2.281		
	Total	668.034	294			
digital skills	Between Groups	3.521	3	1.171	0.524	**0.666**
	Within Groups	654.070	292	2.240		
	Total	657.591	295			
ability to learn	Between Groups	4.202	3	1.401	0.593	**0.620**
	Within Groups	695.009	294	2.364		
	Total	699.211	297			
flexibility, adaptation	Between Groups	5.998	3	1.999	1.069	**0.362**
	Within Groups	542.234	290	1.870		
	Total	548.231	293			
social (ability to get along with other people)	Between Groups	0.240	3	0.080	0.500	**0.985**
	Within Groups	464.565	289	1.607		
	Total	464.805	292			

For each skill category, the significance came out greater than 0.05, i.e., we do not reject H0 at the 0.05 level of significance and this implies that there are no significant differences in skills among workers with respect to digitization and automation of work. For all positions tested, these skills are equally important.

4 Discussion

Due to the advantages and disadvantages of human-machine cooperation, collaboration is very important, a machine can represent a person in certain activities and a person will have more time and energy for other activities that the machine cannot handle (handling more complex parts of products). From the results we analyzed, we came to the conclusion that employees in companies are aware of the need to introduce new technologies, which we can state based on the results focused on the need for skills and abilities. Employees, respondents rated technical (professional) skills as well as digital skills as the most necessary, which is undoubtedly the basis for human-machine cooperation. We can define precise paths of activities and procedures for the machine so that they are economical and efficient for the company, and that is why one will have to develop these two areas of skills, which serve precisely to coordinate with the robot. Cooperation between man-machine opens up new possibilities for advancing not only industry but also everyday life.

Conclusion

In the last decade, technology and technological progress have gone exponentially to the forefront. Today, humanity, science, and industry know the technologies that undoubtedly make people's daily lives easier. Technological progress is still advancing and at present, we cannot even realize what awaits us in the industry in the future, but the application of the Industry 4.0 paradigm, accelerating and improving production processes, focusing on the sustainability of production and production processes in accordance with the 3 dimensions of sustainability (economic, social and environmental). The views of authors [21, 24, 31] and scientific researchers differ. Many authors state in a global sense the negative impact on human-machine cooperation, others discuss the positive impact on man and his work. Man in the production process is an irreplaceable aspect, just like a machine. There must be a definition of areas of work for the machine, for man, and their cooperation. Collaboration in terms of outlining the activities that will be performed by a man and by machine. Defining, for example, specific tasks such as feeding parts to a machine/robot for the human assembly, so that man does not interfere with the production process (feeding parts) of the machine and the machine, robot into human work activities (assembly of parts). Furthermore, to define the distances between the machine or robot and human, if a human approaches a specified distance, which can endanger a human, he must cause the machine to stop its movement, and activity. Defining ergonomic requirements when working with loads, wherein such an activity, the work of the robot is a human aid. The primary purpose of introducing technology, automation, and digitization into the industry is due to a weakening workforce and the facilitation of human activities.

Without the implementation of the basic elements and technologies of Industry 4.0, companies will not be able to constantly adapt to the new challenges that come with this new paradigm. Without basic innovations and implementations within the Industry 4.0 trend, small, medium, and large Slovak companies will not be able to apply technologies that would support human-machine interaction. Employees, especially production workers, based on the current results of a questionnaire survey, more than 65% of employees would say that they generally do not feel threatened by the introduction of new technologies into the company in which they work. More than 85% of employees do not feel threatened by administrative staff. It is the production and administrative staff that are expected to be the most vulnerable groups in terms of the introduction of digitization-related technologies and Industry 4.0.

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References

[1] KAGERMANN. H. 2015. Change Through Digitization-Value Creation in the Age of Industry 4.0. In: *Management of Permanent Change. Springer Fachmedien Wiesbaden, Wiesbaden*, 23–45

[2] SHROUF, F.; ORDIERES, J.; MIRAGLIOTTA, G. 2014. Smart Factories in Industry 4.0: A Review of the Concept and of Energy Management Approached in Production Based on the Internet of Things Paradigm. In: *Proceedings of the 2014 IEEE International Conference on Industrial Engineering and Engineering Management*. IEEE, 697–701. https://doi.org/10.1109/IEEM.2014.7058728

[3] FIFEKOVÁ, E.; NEMCOVÁ, E. 2016. Industry 4.0 and its implications for EU industrial policy. [12-2021]. Available on the Internet: http://www.prog.sav.sk/sites/default/files/2018-03/Priemysel.4.0.a.jeho_.implikacie.pre_.priemyselnu.politiku.pdf

[4] USTUNDAN, A.; CEVIKCAN, E. 2018. *Industry 4.0: Managing The Digital Transformation*; Springer International Publishing: Cham, Switzerland

[5] POTKÁNY, M.; GEJDOŠ, P.; LESNÍKOVÁ, P.; SCHMIDTOVÁ, J. 2020. Influence of quality management practices on the business performance of Slovak manufacturing enterprises. Acta Polytechnica Hungarica. 17, 161–180 s. [2-2022] http://acta.uni-obuda.hu/Potkany_Gejdos_Lesnikova_Schmidtova_106.pdf

[6] ŠOLC, M.; KOTUS, M.; GRAMBALOVÁ, E.; KLIMENT, J.; PALFY, P. 2019. Impact of corrosion effect on the quality and safety of refractory materials. Syst. Saf. Hum. Tech. Facil. Environ. 1, 760–767. https://content.sciendo.com/view/journals/czoto/1/1/article-p760.xml?product=sciendo

[7] https://ec.europa.eu/eurostat

[8] HAYASHIDA, N. 2018. Sensecomputing for Human-Machine Collaboration trough HUman Emotion Understanding. In: *Sci.Tech. Journal*. 54(5)

[9] UNCED. 1992. United Nations Conference on Environment and Development. http://sustainabledevelopment.un.org/index.php?page=view&nr=23&type=400

[10] SHARMA, S.; RUUD, A. 2003. On the path to sustainability: integrating social dimensions into the research and practice of environmental management, In: *Business Strategy and the Environment*, 12(4), 205–214 s.

[11] VAN DER WIELE, T.; KOK, P.; MCKENNA, R.; BROWN, A . 2001. A Corporate Social Responsibility Audit within a Quality Management Framework. In: *J. Bus. Ethics,* **31**, 285–297 s.

[12] UNDSD .2001. Indicators of Sustainable Development: Guidelines and Methodologies. [1-2022] http://www.un.org/esa/sustdev

[13] VALLANCE, S.; PERKINS, H. C.; DIXON, J. E. 2011. What is social sustainability? A clarification of concepts, In: *Geoforum*, 42 (3), 342–348s.

[14] GUGLER, P.; SHI, J. Y. 2009. Corporate social responsibility for developing country multinational corporations: lost war in pertaining global competitiveness?. In: *Journal of Business Ethics*, 87 (1), 3–24 s. https://doi.org/10.1007/s10551-008-9801-5

[15] SARTAL, A. a kol. 2020. The sustainable manufacturing concept, evolution and opportunities within Industry 4.0: A literature review. In: *Sustainable Manufacturing – Review Article*. 12(5). 1 -17s.

[16] WILSON, C. 2018. Designing the purposeful world: the sustainable development goals as a blueprint for humanity. New York: Routledge

[17] DESPEISSE, M.; MBAYE, F.; BALL PD. 2012. The emergence of sustainable manufacturing practices. Prod Plan Control, 23(5): 354–376 s. https://doi.org/10.1080/09537287.2011.555425

[18] BOTHA, A.P. 2016. Developing executive future thinking skills, International Association for Management of Technology, *IAMOT 2016 Conference Proceedings*, 951 – 972 s.

[19] NELLES, J.; KUZ, S.; MERTENS, A.; SCHLICK, Ch. M. . 2016. Human-centered design of assistance systems for production planning and control:

The role of the human in Industry 4.0. In: *2016 IEEE International Conference on Industrial Technology (ICIT). IEEE*, 2099–2104. https://doi.org/10.1109/ICIT.2016.7475093

[20] BRETTEL, M.; FRIEDERICHSEN, N.; KELLER, M.; ROSENBERG, M. . 2014. How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective. *International Journal of Information and Communication Engineering* 8 (1), 37–44 s. doi.org/10.5281/zenodo.1336426

[21] ROMERO, D.; STAHRE, J.; WUESt, T.; NORAN, O.; BERNUS, P.; FAST-BERGLUND, L.; GORECKY, D. . 2016a. Towards an operator 4.0 typology: a human-centric perspective on the fourth industrial revolution technologies. In: *CIE46 Proceedings*. 11(1)

[22] KRUPITZER, C.; LESCH, V.; ZÜFLE, M.; KOUNEV, S.; MÜLLER, S.; EDINGER, J.; BECKER, C.; LEMKEN, A.; SCHÄFER, D. 2020. A Survey on Human Machine Interaction in Industry 4.0. 1(1), 45 s. https://doi.org/10.1145/1122445.1122456

[23] BOSTON CONSULTING GROUP. 2015. Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. [12-2021]. https://inovasyon.org/images/Haberler/bcgperspectives_Industry40_2015.pdf

[24] ZAHIDI, S.; RATCHEVA, V.; LEOPOLD, T.A. 2018. Towards a Reskilling Revolution A Future of Jobs for All. http://www3.weforum.org/docs/WEF_FOW_Reskilling_Revolution.pdf

[25] ROMERO, D.; NORAN, O.; STAHRE, J.; BERNUS, P.; FAST-BERGLUND, A. 2015. Towards a Human- Centred Reference Architecture for Next Generation Balanced Automation Systems: Human-Automation Symbiosis. In: *IFIP International Conference on Advances in Production Management Systems*. 556-566 s. https://link.springer.com/chapter/10.1007%2F978-3-319-22759-7_64

[26] ROMERO, D.; BERNUS, P.; NORAN, O.; STAHRE, J.; FAST-BERGLUND, A. 2016b. The Operator 4.0: Human cyber-physical systems & adaptive automation towards human-automation symbiosis work systems, production management initiatives for a sustainable world. In: *International Federation for Information Processing (IFIP)*, 677-686 s.

[27] ROMERO, D.; STAHRE, J.; TAISCH, M. 2020. The Operator 4.0: Towards socially sustainable factories of the future. In: *Computers and Industrial Engineering.* 139. https://doi.org/10.1016/j.cie.2019.106128

[28] MAC, T. T., LIN, CH-Y. HUAN, N. G., NHAT, L. D., HOANG, P. C., HAI, H. 2021. Hybrid SLAM-based Exploration of a Mobile Robot for 3D Scenario Reconstruction and Autonomous Navigation. *Acta Polytechnica Hungarica.* Vol. 18, No. 6

[29] HANCOCK, P.A.; JAGACINSKI, R.J.; PARASURMAN,R. WICKENS,C.D.;WILSON, G.F.; KABER, D.B. 2013. Human-automation interaction research: past, present and future. In: *Q.Hum. Factors Appl*. 21(2), 9-14 s. https://doi.org/10.1177/1064804613477099

[30] FASTH-BERGLUND, A.; STAHRE, J. 2013. Cognitive automation strategy- for reconfigurable and sustainable assembly systems. In: A*ssembly Autom.* 33(3), 294-303 s. https://doi.org/10.1108/AA-12-2013-036

[31] BOTHA, A.P. 2016. The Future of Artificial Intelligence – The Human-Machine Frontier, Foresight for Development, [1-2022] http://www.foresightfordevelopment.org/featured/artificial---intelligence---ii. http://foresightfordevelopment.org/featured/artificial-intelligence-ii

[32] LUKAČEVIĆ, F., ŠKEC, S., MARTINEC, T. 2022. Challenges of Utilizing Sensor Data Acquired by Smart Products in Product Development Activities. *Acta Polytechnica Hungarica.* Vol. 19, No. 4

[33] THOMAS, D. 2016. Costs, benefits, and adoption of additive manufacturing: A supply chain perspective. Int. J. Adv. Manuf. Technol. 85, 1857–1876. http://dx.doi.org/10.1007/s00170-015-7973-6

[34] USTUNDAN, A.; CEVIKCAN, E. 2018. Industry 4.0: Managing The Digital Transformation; Springer International Publishing: Cham, Switzerland

[35] LEGASHEV, L. V., BOLODURINA, I. P. 2020. An Effective Scheduling Method in the Cloud System of Collective Access, for Virtual Working Environments. *Acta Polytechnica Hungarica.* Vol. 17, No. 8