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# SUSTAINABLE INDUSTRY ROBOTIZATION

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**Abstract**

The transformation to Industry 4.0 increases the number of robots' installations within the industry, which brings various concerns. The paper focuses on changes in manufacturing sector in the last decade, and on the expected future development. Based on analysis of official and publicly available data we expose the decreased number of jobs and a contracting share of manufacturing output within the industry. We also compared data on industrial robots' shipments and labour productivity in manufacturing, to present negative correlation.

We are entering the so-called "robots stealing jobs period" and great shifts in industry ecosystem and society as a whole are happening. Implication of presented research is to increase awareness of some missed economic and also social goals of transformation to Industry 4.0, calling for new strategic directions for industry humanization and economic eligibility. For this reason, we believe the opportunities for further development in this field should be carefully examined and oriented toward more sustainable and human friendly industry transformation.

**Keywords:** industry transformation, industry robotization, social sustainability, manufacturing output, productivity in manufacturing;

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## Introduction

The paper focuses on the robotization of industry, which happens accelerated in this century, especially now, during the transformation to Industry 4.0, using the data by International Federation of Robotics (IFR) on shipments of multipurpose industrial robots. Furthermore, based on official dataset on number of jobs, outputs and productivity, in manufacturing sector and industry as a whole in the United States (U.S.) we present an alternative view on the current situation in industry.

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We noticed that the increased number of robots within the industry, capable of learn, interact and understand, poses threat to human's role in industry. This implies that the latest transformation of industry has to be carefully examined and planned sustainably, due to the possible significant negative impact on the society as a whole. For this reason, we decided to focus on the next step of industry transformation, from Industry 4.0 to Industry 5.0, in which human role should again be increased and considered as a main driver of growth and success in globalized economy.

Rapid development of technology enables changes in industry as a whole, while the recent technology focus on manufacturing sector exposes the transformation in direction of *factories of the future*. Factories of the future are enabled by management and control systems, quality assurance, data regulation and processing, intralogistics, digitalization, optimization and automatization of production processes. Based on a comprehensive technological restructuring, factories of the future are also raising the level of robotization and are linking knowledge and creativity, enabling the increase of added value per employee, new market opportunities and an increase in exports. The factories of the future are a new dimension of multi-level production that take advantage of the latest ubiquitous and pervasive information technologies.

The industry's focus moved on funding of such advanced technological solutions to increase outputs and productivity. But, there is a big gap between technology change and business productivity (Deloitte, 2017b). For this reason, the aim of the paper is also to expose different view on this industry transformation as in the official public documents, only positive consequences of Industry 4.0 are put to front. However, looking at certain economic indicators, and considering social consequences, alternative view arises.

The following two chapters of the paper present short theoretical framework on the Industry 4.0 and further development to Industry 5.0. The fourth chapter describes the research goal and sets out the hypothesis. The following two chapters present data analysis and summarize our key findings. The last chapter puts forward an alternative view on the theoretical framework of Industry 4.0 and discusses the possibilities about the required changes for human friendly industry transformation.

## Literature Review

The fourth industrial revolution, also named as Industry 4.0, is one of the most trending topics in both professional and academic fields (Chiarello et al., 2018; Liao et al., 2017). The first three industrial revolutions were a result of mechanization, electricity and information technology, while in the 4th industrial revolution internet of things and cyber physical systems were introduced into the manufacturing environment (Weyer et al., 2015).

In terms of cyber physical systems, it can be considered that we are in the middle of the 4th industrial revolution. These systems are industrial automation systems with several innovative functionalities. These innovative functionalities are enabled by the networking and their access to the cyber world (Jazdi, 2014). For instance, smart sensors and actuators, which enable real-time responses and decisions, are increasingly being introduced, through integrated computer support and become more and more self-sufficient over the time due to low energy consumption (Rojko and Jelovac, 2018). The Industry 4.0 technological field is not new, but it is highly heterogeneous (actually it is the aggregation point of more than 30 different fields of the technology). For this reason, many stakeholders feel uncomfortable, since they do not master the whole set of technologies, and they manifested a lack of knowledge and pointed several problems of communication with other domains (Chiarello et al., 2018).

Integration of technological solutions requires comprehensive exchange of production and business information. Only based on this exchange it is possible to increase optimization and efficiency of the entire range of production processes: from identifying market needs, planning, modeling and manufacturing a new product, to planning production resources, logistics and stock management (Gianelle et al., 2016).

Industry 4.0 technologies can be separated, at least, into two different layers according to their main objective, as proposed in our conceptual framework. In the center of the framework we place what we call as 'Front-end technologies' of Industry 4.0, which considers the transformation of the manufacturing activities based on emerging technologies (Smart Manufacturing) and the way product are offered (Smart Products) (Dalenogare et al., 2018).

The strategic directions of development in the industry include the integration and upgrade of technologies that are already present in the factories, but need to be upgraded and updated at all time. In this regard smart factories combine their solutions for sharing and monitoring, based on a comprehensive integration of manufacturing facilities and technologies. In smart factories management methods and control that were used up to now at the level of individual machines and devices, expand to the entire production lines and, finally, the entire factory (Rojko and Jelovac, 2018). Regarding the Smart Manufacturing dimension, we subdivided the related technologies into six main purposes: vertical integration, virtualization, automation, traceability, flexibility and energy management (Frank et al., 2019).

In repeating processes, the automated processes can eliminate the so-called human error, while automation and robotization is also solution for difficult and hazardous areas of work, where certain tasks have to be automated due to the high risk of injuries at work or permanent damage. The basis of automation also comes from the need to reduce production costs and increase the precision of production, which ultimately allows greater competitiveness in the global market, especially if all automated processes are interconnected.

Besides automation also digitalization enables the integration of all internal work processes, along with including suppliers and customers in the company network. Industry 4.0 has been considered a new industrial stage in which several emerging technologies are converging to provide digital solutions (Frank et al., 2019). Here also the paradigms of the Internet of Things and the Internet of Services play an important role, as both paradigms underlie the transition to Industry 4.0.

The term Internet of Services refers to an open, flexible, and standardized enablers that facilitate the harmonization of various applications into interoperable services, as well as the use of semantics for the understanding, combination and processing of data and information from different formats, sources and service provides (Hernández-Muñoz J.M. et al., 2011), while the term Internet of Things is used for combination of digital and physical components to create novel business models and create new products (Wortmann and Flüchter, 2015).

Linking workflows within manufacturing companies is a lengthy process, as it requires ubiquitous smart sensors, actuators, their connectivity to ICT hardware and the appropriate ICT software (EFFRA, 2016). The transition to Industry 4.0 thus requires a long-term investment in company sources. This raising level of digitization, automatization and robotization, enable the technological restructuring.

The evolving processes and technologies within production are enabled by production strategies, modeling, simulations, methods and tools for analytics and forecasting, mechatronics for advanced production systems, as well as senior educated workers. This new industrial stage demands a socio-technical evolution of the human role in production systems (Frank et al., 2019). There has already been seen some transformation of the industry to Industry 4.0 and next stage is ahead - the development of the upcoming industry-specific paradigm 5.0, which supposed to be industry with the "human touch" (Gotfredsen, 2016).



Physical, biological, and digital worlds began merging, to give us the "Fusion Revolution", disrupting whole industry and giving a rise to the new mantra - the more things change, the quicker things change (Engelbert, 2017). All these simultaneous changes also strongly influence the society and people. For this reason, family life, globalization, markets, etc. will have to be redefined (Jazdi, 2014).

More advanced companies, which have already adopted the measures of the transition to Industry 4.0, are therefore oriented towards the future. For this reason, it is the last time to prepare new basic directions for the sustainable industry development, and we believe, that we should put human back to the foreground, and by doing this, to give human workers the reason for their presence in industrial processes. To make it possible, there is a need to change companies' and governments' strategies, and based on to orient towards the direction of employing and educating competent, highly qualified profiles in the manufacturing sector that would be able to cope with the new reality. This would also help to turn certain negative economic trends back upwards and enable greater exploitation of deployed technologies and installed robots, which currently are mostly not fully exploited.

Linking knowledge and creativity in combination with the achievements of Industry 4.0 allows a new step in the development of industry, into the Industry 5.0, which needs to be oriented to humanization, and for this reason the preparation of the updated strategies is required, as rapid development, accelerated digitization and industry robotization, require changed approach for further human friendly transformation.

Namely, industrial robots empowered with cognitive technology can understand reason, talk, interact, explain, support and learn. New robots can also deal with dynamic and unstructured environments, such as those found in shipyards or civil engineering projects and can easily be reconfigured to perform different tasks (Faíña et al., 2011).

Thus, we need a new strategic approach based on in-depth analysis to underlie the further development to Industry 5.0, and that would give the job back to human, since in the automation systems, robots, sensors, etc. installed within transformation to Industry 4.0, replaced him.

Therefore, further transformation should be directed to advanced industry's recycling - connecting of virtual and physical. In order to achieve these transformation goals, coordinated effort, innovation and underlying strategic planning is required.



**Research goal**

We are aware that besides in next chapter presented impact factors from U.S Bureau and IFR data also others have significant impact on economic and social sustainability of developments in industry, as e.g. the education level, area of operation (e.g. automotive, pharmacy, electronics…), rate of development at each stage from national level to individual company level, etc.

Nevertheless, we decided to focus on publicly available quantitative data available on worldwide number of jobs, productivity, output and robot shipments, while we also decided to expose situation in U.S., as one of the most robotized economies worldwide. We also researched other studies of Industry 4.0 impacts, to find explanations for observed situation, as the reliability of U.S Bureau data enabled us to make credible conclusions.

Based on these limitations, we have set the following thesis:
The transformation to Industry 4.0 in manufacturing sector brought negative economic and moreover social consequences. For this reason, we believe the opportunities for further development in this field should be carefully examined and oriented toward sustainable and human friendly transformation to Industry 5.0.

For this reason, manufacturing industry should be transformed based on innovations that are available and offer competitive advantages (Gianelle et al., 2016). Currently, the research priorities of the Industry 4.0 include: efficient use of resources, collaboration digital and virtual factories, customer-focused production, flexible and smart production systems, advanced production processes, mobility, and human-oriented production. Research of these areas focus on measurable and concrete aims that are described as opportunities and challenges for production. According to Gianelle et al. (2016) these are: production of future products, environmental sustainability of production, economic sustainability of production, and social sustainability of production.

The latter two of these goals, economic sustainability of production and social sustainability of production, are in our research focus. Integration of human capabilities with technology, is here essential, since many workers are worried about the same thing. They recognize the benefits of automation in terms of productivity and economic growth, and they see it providing opportunities for value-added or creative activities, or learning new skills. Nonetheless (Deloitte, 2017a):

- 40% of survey's respondents see automation posing a threat to their jobs,
- 44% believe there will be less demand for their skills,
- 51% believe they will have to retrain, and
- 53% see the workplaces are becoming more impersonal and less human.

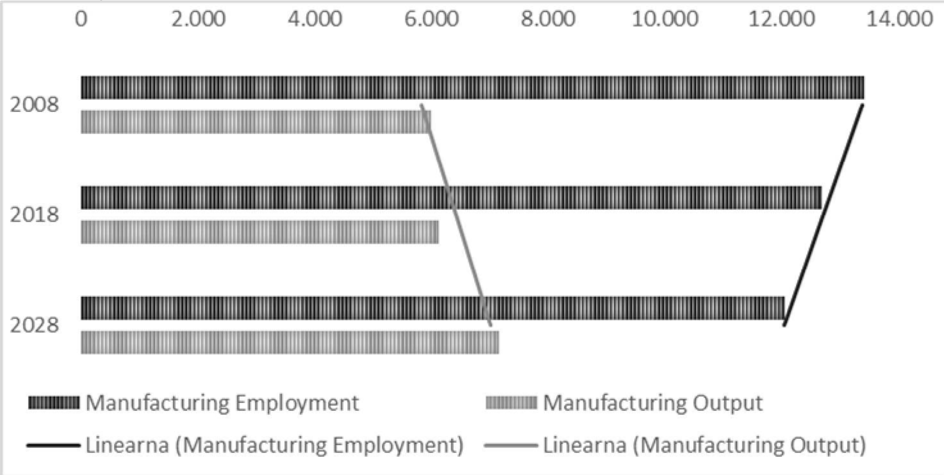
We argue that such concerns should be taken very seriously, since, with no exception, technologies (will) change what we do. All tasks that are highly manual, routine, and predictable will all soon be automated, while AI and robots are already replacing human in many industry processes. For this reason, this development needs to be strategically regulated on companies', but firstly on national and transnational levels, to enable socially sustainable transition. There is a possibility that the manufacturing sector will see the same development as farming in the past century. As David Autor (Deloitte, 2017a) has observed: "If you had told an American farmer in 1900 that, the coming century would bring a 95% reduction in farm employment, he wouldn't believe it, but it nonetheless happened."

Engineers and blue-collar workers need new life-long learning schemes to keep up with the pace of change. Namely, the rapid advancements in manufacturing technology and in information and communication technologies require an intense and continuous update of their knowledge, which is essential for their integration and smooth adaptation into the industrial working practice (Mavrikios et al., 2013). The robotization of industry thus requires linking knowledge and creativity in combination with the achievements of Industry 4.0, to increase back the human role. Our goal is to show that the current transition to Industry 4.0. does not bring all expected economic and social benefits, while it is bringing great changes in society and possible threat to the end of humanity in industry. Addressing these challenges should therefore be a major part of the research in this field.

**Data Analysis**

We decided to use official and publicly available data to support our thesis, since such data allows for greatest reliability and based on solid conclusions. Hereby we present U.S. Bureau data (2019a and 2019b) including number of jobs and outputs in companies from manufacturing sector and in the industry on general in the U.S. and data on productivity in manufacturing sector. Besides, we also provide insight into the number of industrial robots' shipments based on IFR data (2019), which sees enormous growth in the past decade and is projected to continue to grow rapidly. In addition, within this chapter, we focus on the comparison of U.S. Bureau and IFR data, where negative correlation between industrial robots' shipments and labor productivity in U.S. manufacturing sector is exposed, while we also present estimated multipurpose robot shipments in the next decade based on linear line.

Figure 1: Number of jobs (thousands of jobs) and output (billions of dollars) - companies from manufacturing sector in the U.S. (years 2008 to 2028)




Source: U.S. Bureau of Labor Statistics, 2019a.

The number of jobs in the U.S. grew for 7.9% from 2008 until 2018, while the compound annual growth rate (CAGR) of 4.3% from 2008 until 2028 in the industry as a whole is expected. Also, the total output grew for 15.0% in the past decade and CAGR of 11.5% (constant 2011 dollars) is expected in the 2008-2028 period (U.S. Bureau of Labor Statistics, 2019a). On the other hand, figure above shows that in manufacturing sector employment declined for 5.4% from 2008 to 2018, but on the contrary manufacturing output managed to grow 2.4%. Based on further projections we can expect CAGR decline of 3.5% in manufacturing employment from 2008 till 2028, and CAGR growth in manufacturing output of 6.2%.

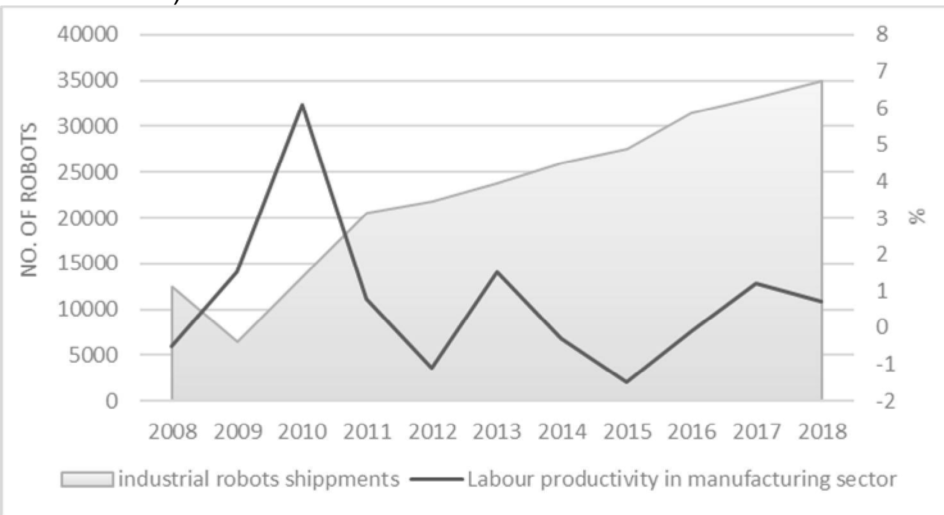
These data show that in the U.S.:

- employment will continue grow in industry as a whole, but not in the manufacturing sector,
- output will exhibit further growth in both industry as a whole and in manufacturing, but in manufacturing at an almost a half lower

rate, which means manufacturing share in total output will continue to decrease,
- despite forecasted output growth of manufacturing sector there will be further decline of jobs in this sector.

We can expect same trends to be observed worldwide, and especially in countries that are the more competitive, e.g. the U.S. topped the rankings in Global Competitiveness Report (World Economic Forum, 2018), being 'closest to the competitiveness frontier', with Singapore, Germany, Switzerland and Japan, completing the top five.

Figure 2: Number of shipped industrial robots vs. labor productivity (percent change from year ago) in the U.S. manufacturing sector (years 2008 to 2018)



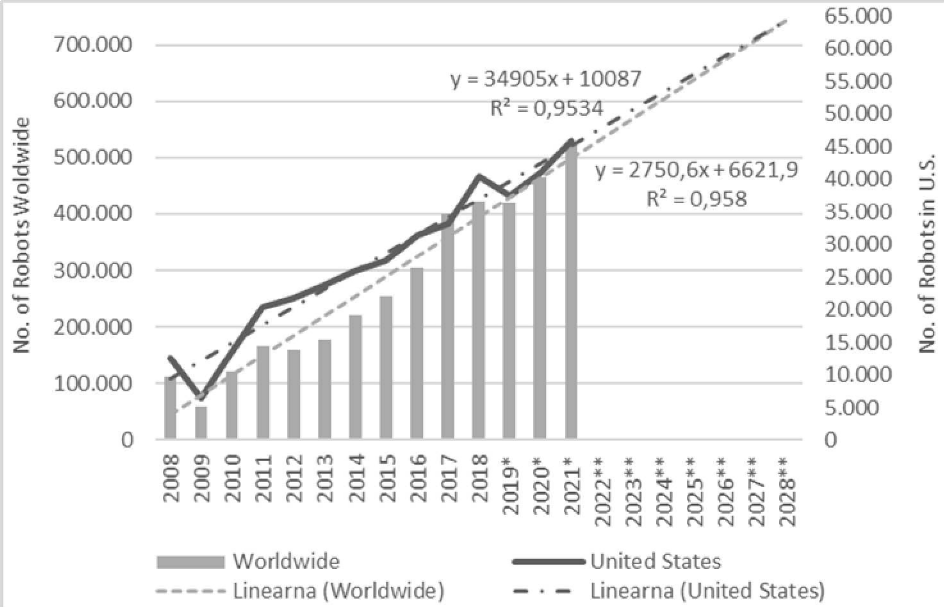

Source: U.S. Bureau data of Labour Statistics, 2019b and IFR, 2019.

Figure 2 presents the number industrial robots' shipments' in the U.S., which grew at CAGR of 9.8% from 2008 until 2018, while the productivity in manufacturing is still low; it was even negative in 5 years of this timeframe. The greatest year-over-year growth of 6.1% was recorded in 2010, and strongest decline of 1.5% was measured in 2015, on average recording 0.8% growth.

Tested correlations moreover showed us negative correlations: between labour productivity in manufacturing sector in U.S. and industrial robot shipments the Pearson's coefficient shows small negative correlation (-0.29), and also the Spearman coefficient shows small negative correlation (-0.25), in the 2008-2018 period. However, we nonetheless have to keep in mind, that the reasons behind weak labour productivity growth can be several and different, and not only related to the introduction of robots.

Josefsson in Lindeberg (2018) also claims: "Robots are now everywhere, except in the productivity statistics", which can be understood as the modern productivity paradox. This reminds us to the Solow's famous theorem "You can see the computer age everywhere but in the productivity statistics." But on the other hand, IFR (2017) exposes the different view, claiming: "Robots increase productivity and competitiveness", and "Robots substitute labour activities but do not replace jobs."

Figure 3: Annual shipments (number of units) of multipurpose industrial robots worldwide and in the United States from years 2008 to 2028* (2008-2018 - actual, 2019-2021 - estimated by the source used, 2022-2028 - projected)




Source: IFR, 2019.

In 2018 the estimated U.S. annual supply of multipurpose industrial robots reached more than 40 thousand units, and comprised 9.6% of the worldwide supply (IFR, 2019), namely in this year the total number of worldwide robots' shipments reached more than 420,000 units. Moreover, based on the actual (2018) and estimated IFR data (2019*-2021*) the linear trendline shows the expected further growth of shipments to reach more than 64 thousand units in 2028, capturing 8.6% of worldwide supply. The decreased (2018 vs. 2028) share of industrial

shipment supply is expected mainly due to maturity of industry in the U.S.
Shipments to Europe were almost at double the shipments to U.S. in 2018, when 76 thousand units were shipped to European countries. Among individual countries China lead in 2018 based on 36.5% share with more than 154,000 multipurpose industrial robots shipped to, while Japan was the second and Republic of Korea the third, with 55 and 38 thousand units respectively.

In 2018, the average global robot density[2] of 99 industrial robots installed per 10,000 employees was measured in the manufacturing industry (IFR, 2019). The most automated countries in the world are the Republic of Korea, Singapore, Germany, and Japan (IFR, 2018). With an average of 114 units, Europe is the region with the highest robot density, while the Americas the second with 99 units, followed by Asia/Australia with 91 units (IFR, 2019).

**Discussion**
Transition to Industry 4.0 requires significant and long-term investments. New technological opportunities facilitate performance changes of manufacturing companies and offer possibilities for increased productivity and profits, but only if successfully exploited.

Simpler tasks with lower required qualifications are taken by machines, robots, etc. But despite the introduction of an increasing number of automatic lines and robots, the number of employees is not decreasing in industry on general. As now as in the future, there will be constant need for new knowledge and competences, and thus the need for professionals, developers, maintainers and operators of more and more demanding production systems and devices. Besides, a human is capable of evolutionary learning, moral acting and intuition, which enables creativity and customization, while consumers of the future just demand this – creative and customized products (Rojko and Jelovac, 2018).

Due to the investments in technology (robots' installations, automatic guided vehicles and automatic machines, robotic cells etc.), manufacturing companies simultaneously have to create new high-tech

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[2] When comparing the distribution of multipurpose industrial robots in various countries (IFR, 2018), the robot stock, expressed in the total number of units, can sometimes be a misleading measure. In order to consider, the differences in the size of the manufacturing industry in various countries, it is preferable to use a measure of robot density. The measure of robot density is the number of multipurpose industrial robots per 10,000 persons employed in manufacturing industry.

work places. These changes require different types of employment, according to the factories of the future orientations. New workers' profiles will have more responsibilities, while also more authority in co-operation with robots. Besides, they will have to upgrade their knowledge and skills constantly to prevent robots to take over their jobs.



The concerns over Industry 4.0, in which humans are displaced by robots and in which artificial intelligence and robots become an existential threat to the existence of human in industry processes, has to be taken into the account in creation of the strategy for national and transnational frameworks for further industry development.

Cyclical trends in economic growth and the emerging cycle of economy, which requires the development of production of future products, economic sustainability of production, environmental sustainability of production, and social sustainability of production, is already indicating a shift in the direction towards the collaborative approaches and the integration of human and technology, which is the basic idea of Industry 5.0. Nonetheless, it is necessary to regulate this development, otherwise, robots would be able to replace human workers in industry, which would lead to even greater social unsustainability. For this reason, the predicted implication of our research is the increased awareness of missed goals of transformation to Industry 4.0 from social and also economic point of view, meaning new strategic directions for industry development are mandatory, in which humanization must be highlighted as the most important.

## Conclusion

The scientific contribution of our research is explained by fact that other studies have not investigated the influence of accelerated industry development from the perspective of changes in the society, which are much slower than the changes in technology used in industries. Data and sources analysis enabled us to develop an alternative view on the current industry transformation, and we identified the need for different strategic planning for industry's sustainable development.

Based on presented data above and concerns regarding the future role of human workers expressed elsewhere (e.g. in Deloitte's survey, 2017a) we can confirm our thesis that the transformation to Industry 4.0 in manufacturing sector brought negative economic and moreover social consequences. Namely, the number of employees in the manufacturing sector in the U.S. market was declining during the past decade (2008-2018) and is projected to continue to exhibit this trend in next decade (2018-2028), in contrast to the growing number of employees on general in all sectors. On the other hand, data (U.S. Bureau of Labor Statistics, 2019a) show that the share of output of companies from manufacturing sector in comparison to industry as a whole in the U.S. contracted in the past decade, and further decline is expected in the next decade. Furthermore, Figure 2 projects unexpectedly low productivity growth in the U.S. manufacturing sector in the past decade. Statistical data processing also exposed small negative correlation between productivity and the number of robots shipped.

Having this in mind, data on robust robotization (IFR, 2019) indicate that significant investments in the multipurpose robots in the U.S. did not prevent output share decline of manufacturing and also did not bring productivity gains within this sector, which is a clear indicator of missed goals.

We can thus agree with Glaser and Molla (2017) arguing, that more robots also mean fewer jobs. Robots are namely getting less expensive and more capable, which is why more robots are replacing human workers. Also, for this reason, the situation requires immediate governmental attention on national and transnational level, since factory owners are expected not to pay (enough) attention to the social consequences of this trend, focusing on profits in the first row.

Furthermore, the presented data show that in the U.S. employment will continue grow in industry as a whole, but not in the manufacturing sector, and that despite forecasted output growth of manufacturing sector there will be further decline of jobs in this sector. We can expect same trends to be observed worldwide, and especially in countries that are more competitive since the U.S. topped the rankings in Global Competitiveness Report (World Economic Forum, 2018).

The social sustainability of production requires the integration of human and technology. Industry 4.0 stage thus demands a socio-technical evolution of the human role in production systems (Frank et al., 2019), meaning there is increasing demand for new human workers' knowledge about technologies, to install, optimize and control them, while the emphasis must also be on the effective analysis, communication, self-initiative acting and creativity. Only by such new knowledge gains, we can expect increase of human role, which is the main aim of Industry 5.0.
Industry 5.0 is expected to focus primarily on human and robot engagement and the integration of human knowledge, skills, experience, etc. within robotized production, while a higher degree of reliability, flexibility, creativity, self-initiative acting, accuracy, fast learning and

moral responsibility will be expected from employees. Moreover, Industry 5.0 should return the job back to the human and give him the reason for his presence in industrial processes. The further transition of industry should therefore be strategically planned and oriented towards the integration of virtual and physical, considering changed role of the workers in modern industry production.

## References

Chiarello, F., Trivelli, L., Bonaccorsi, A., and Fantoni, G. (2018). Extracting and mapping industry 4.0 technologies using wikipedia. Computers in Industry, 100, 244-257. Available at: https://doi.org/10.1016/j.compind.2018.04.006 (accessed 5 January 2020).

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., and Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of Production Economics, 204, 383-394. Available at: https://doi.org/10.1016/j.ijpe.2018.08.019 (accessed 9 November 2019).

Deloitte (2017a): The Deloitte Millennial Survey 2017, Available at: https://www2.deloitte.com/global/en/pages/about-deloitte/articles/millennialsurvey.html (accessed 8 September 2019).

Deloitte (2017b): 2017 Deloitte Global Human Capital Trends, Available at: https://www2.deloitte.com/us/en/pages/human-capital/articles/introduction-human-capital-trends.html (accessed 8 September 2019).

EFFRA (2016): Factories 4.0 and Beyond. Recommendations for the work programme 18-19-20 of the FoF PPP under Horizon 2020, Available at: http://www.effra.eu/sites/default/files/factories40_beyond_v31_public.pdf (accessed 15 November 2019).

Engelbert, C. (2017): Job-Stealing Robots? Millennials See Hope, Fear in Automation. Deloitte, 21 March 2017, Featured in: Millennials, Technology, Your Career.

Faíña, A., Bellas, F., Souto, D. and Duro, J. R. (2011): Towards an Evolutionary Design of Modular Robots for Industry. International Work-Conference on the Interplay between Natural and Artificial Computation 2011: Foundations on Natural and Artificial Computation, pp. 50-59, Springer Link.

Federal Reserve Economic Data (2018). Manufacturing Sector: Labor Productivity. Available at: https://fred.stlouisfed.org/series/MPU9900063 (accessed 31 August 2019).

Frank A. G., Dalenogare L. S., and Ayala N.F. (2019): Industry 4.0 technologies: Implementation patterns in manufacturing companies.

International Journal of Production Economics, 210,15-26. Available at: https://doi.org/10.1016/j.ijpe.2019.01.004 (accessed 5 January 2020).

Gianelle, C., Kyriakou, D., Cohen C. and Przeor, M. (eds) (2016): Implementing Smart Specialisation: A Handbook. Brussels: European Commission, Available at: http://www.svrk.gov.si/fileadmin/svrk.gov.si/pageuploads/Dokumenti_za_objavo_na_vstopni_strani/S4_S3_Handbook.pdf (accessed 9 November 2019).

Glaser, A. and Molla, R. (2017): The number of robots sold in the U.S. will jump nearly 300 percent in nine years. Job-stealing robots are steadily taking over America. Recode, 3 April 2017, Available at: https://www.recode.net/2017/4/3/15123006/robots-sold-america-growth-300-percent-jobs-automation (accessed 9 November 2019).

Gotfredsen, S. (2016): Bringing back the human touch: Industry 5.0 creating factories of the future. PACE magazine, June 29, 2016, Available at: https://pacetoday.com.au/bringing-back-the-human-touch-industry-5-0-creating-factories-of-the-future/ (accessed 8 September 2019).

Hernández-Muñoz J.M. et al. (2011): Smart Cities at the Forefront of the Future Internet, in: Domingue J. et al. (eds), The Future Internet, FIA 2011, Lecture Notes in Computer Science, vol 6656. Springer, Berlin, Heidelberg.

IFR (2017): The Impact of Robots on Productivity, Employment and Jobs, a positioning paper by the International Federation of Robotics, April 2017, Available at: https://ifr.org/img/office/IFR_The_Impact_of_Robots_on_Employment.pdf (accessed 7 October, 2019).

IFR (2018): Robot density rises globally. IFR Press Release, February 07, 2018, Frankfurt, Available at: https://ifr.org/ifr-press-releases/ (accessed 20 February 2019).

IFR (2019): Executive Summary World Robotics 2018 Industrial Robots. Available at: https://ifr.org/downloads/press/Executive_Summary_WR_2018_Industrial_Robots.pdf (accessed 20 November 2019).

Jazdi, N. (2014): Cyber physical systems in the context of Industry 4.0. 2014 IEEE International Conference on Automation, Quality and Testing, Robotics, Cluj-Napoca, 2014, 1-4. Available at: http://10.1109/AQTR.2014.6857843 (accessed 7 October, 2019).

Liao, Y., Deschamps, F., Loures, E. D. F. R., and Ramos, L. F. P. (2017). Past, present and future of Industry 4.0-a systematic literature review and research agenda proposal. International journal of production research, 55(12), 3609-3629. Available at:

https://doi.org/10.1080/00207543.2017.1308576 (Accessed 7 January 2020).

Lindeberg, R. (2018): Robots Are Now Everywhere, Except in the Productivity Statistics. Bloomberg, 10. April 2018, Available at: https://www.bloomberg.com/news/articles/2018-04-10/robots-are-now-everywhere-except-in-the-productivity-statistics (accessed 10 October 2019).

Mavrikios, D., Papakostas, N., Mourtzis, D. and Chryssolouris, G. (2013): On industrial learning and training for the factories of the future: a conceptual, cognitive and technology framework. Journal of Intelligent Manufacturing, June 2013, Volume 24, Issue 3, pp 473–485, Springer Link.

Rojko, K. and Jelovac, D. (2018): Human role in factories of the future. in Zbornik radova, IPI Akademija, Tuzla, pp. 165-178.

Sparkes, M. (2015): Top scientists call for caution over artificial intelligence. The Telegraph, UK, April 24, 2015, Available at: https://www.telegraph.co.uk/technology/news/11342200/Top-scientists-call-for-caution-over-artificial-intelligence.html (accessed 18 October 2019).

Trading Economics (2017): United States Corporate Profits, 1950-2017. Available at: https://tradingeconomics.com/united-states/corporate-profits (accessed 9 November 2019).

U.S. Bureau of Labor Statistics (2019a): Employment Projections program. Available at: https://www.bls.gov/emp/data/industry-out-and-emp.htm (accessed 20 December 2019).

U.S. Bureau of Labor Statistics (2019b) Division of Major Sector Productivity. Available at: https://www.bls.gov/lpc/ (accessed 20 December 2019).

Weyer, S., M. Schmitt, M. Ohmer and Gorecky D. (2015): Towards Industry 4.0 - Standardization as the crucial challenge for highly modular, multi-vendor production systems. IFAC-PapersOnLine, Volume 48, Issue 3, 2015, Pages 579-584. Available at: https://doi.org/10.1016/j.ifacol.2015.06.143 (accessed 7 October 2019).

World Economic Forum (2018): The Global Competitiveness Report 2018. Available at: http://www3.weforum.org/docs/GCR2018/05FullReport/TheGlobalCompetitivenessReport2018.pdf (accessed 9 November 2019).

Wortmann, F. and Flüchter, K. (2015): Internet of Things Technology and Value Added. Business & Information Systems Engineering, 57: 221, Available at: https://doi.org/10.1007/s12599-015-0383-3 (accessed 7 October 2019).