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The Analysis of the Level of Implementation of Industry 4.0 Solutions in European Companies

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Abstract
The new challenges faced by companies in the 21st century require great flexibility and innovation. The fourth industrial revolution drives the development of the global market, and its solutions bring many benefits to companies, e.g. lowering operating costs, increasing the efficiency of information and inventory management, they also give the opportunity to quickly respond to changing customer needs. The study presents selected technologies used by European companies in the era of Industry 4.0 and the analysis of the current state in the context of the level of individual technologies in the EU countries. The analysis concerns large companies and the SME sector.

Keywords: industry 4.0, fourth industrial revolution

1. INTRODUCTION

Dynamic changes in the tastes, needs and requirements of consumers are a stimulus that causes significant changes in the functioning of many enterprises. The basic element of customer loyalty to companies is the quality of products or services

provided, but in the long term, the ability to adapt to customer needs may be more important than quality. Industrial revolutions contributed to the development of the world economy and in some way influenced the level of the quality of life in society. The invention of the steam engine in the mid-18th century (the first industrial revolution) resulted in industrialization - the development of the industrial sector[1]. The second industrial revolution (the second half of the nineteenth century) was characterized by a major breakthrough in the field of production - thanks to the use of electricity, mass production appeared, the effect of which was reduction in production costs and at the same time increase in the availability of goods to society. In the era of the third industrial revolution, a key shift took place in many sectors - the advantage of the consumer market. From that moment on, it was companies that started to fight for the customer through process optimization, automation and the use of innovative solutions in the field of management and customer service. The third industrial revolution is still ongoing, but for several years there has been talk of the fourth revolution - Industry 4.0[2].

The aim of the article is to analyze Industry 4.0 solutions and the current state of use of these solutions in small, medium and large enterprises operating in the European Union. The author proposes a hypothesis about a significant difference in the level of implementation and application of digital technologies in the SME sector and in large enterprises dealing with production, transport and storage.

2. LITERATURE OVERVIEW

The concept of Industry 4.0 first appeared in Germany in 2011. At that time, the given term was defined as a strategy for the development of the German economy after the crisis of 2008[3]. In many studies, the term Industrial Revolution 4.0 or Industry 4.0 appears instead of the term Industry 4.0. Regardless of the name, it is a concept that is based on the use of advanced digital and information technologies

1 Płaczek E., *Logistyka w erze Industry 4.0*, "Przedsiębiorczość i Zarządzanie", 19 (2018)/11, pt. 3, pp. 55-66.

2 Bujak A., *Rewolucja przemysłowa-4.0 i jej wpływ na logistykę XXI wieku*, "*Autobusy: technika, eksploatacja, systemy transportowe*", 18 (2017)/6, pp. 1338-1344.

3 Zhou K., Liu T., Zhou L., *Industry 4.0: Towards Future Industrial Opportunities and Challenges*, [in:] *12th International Conference on Fuzzy Systems and Knowledge Discovery, FSKD 2015, Zhangjiajie, China, August 15-17, 2015. IEEE 2015*, Zhangjiajie 2016, pp. 2147–2152.

as key for the development of intelligent production processes, primarily in the industrial sector[4].

There are many definitions of the Industry 4.0 concept in the literature. H. Lasi claims that Industry 4.0 "describes the increasing digitization and automation of the production environment as well as the creation of digital value chains to enable communication between products, the environment and business partners.[5]" In turn, H. Kagermann, J. Helbig, A. Hellinger and W. Wahlster define Industry 4.0 as "a network of autonomous production resources, able to control themselves in response to various situations, self-configuring, knowledge-based, equipped with sensors and spatially dispersed. as well as covering appropriate management systems."[6] In other words, machines and production devices use integrated communication systems to send data to other machines, as well as download data from the product (e.g. using RFID technology) for further guidance on the production process. K.Zhou describes Industry 4.0 as "fast and disruptive changes involving digital manufacturing, network communication, computer technology and automation."[7]

The era of Industry 4.0 has also been called the era of digital transformation. Industry 4.0 is characterized by the use of the Internet and digital data processing tools as key in the company's development. This concept combines a set of technological innovations:

1. The Internet of Things - A set of technologies that connect all devices via the Internet for remote control and management.
2. The Internet of Services - a system that connects and integrates the functionality of other services.
3. CSP systems (cyber-physical systems) - intelligent structures (including machines) that can make decisions in an autonomous mode and communicate with teams from around the world. These machines should have a high degree of computerization and automation, as well as use AI algorithms.

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4 Weyer S., Schmitt M., Ohmer M., Gorecky D., *Towards Industry 4.0 – Standardization as the crucial challenge for highly modular, multi-vendor production systems*, "IFAC-PapersOnLine", 48 (2015)/3, pp. 579–584.

5 Lasi H., Fettke P., Kemper H.G., Feld T., Hoffmann M., *Industry 4.0*, "Business & Information Systems Engineering", 6 (2014)/4, pp. 239–242.

6 Kagermann H., Helbig J., Hellinger A., Wahlster W., *Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0: Securing the Future of German Manufacturing Industry. Final Report of the Industrie 4.0 Working Group*, Forschungsunion, Frankfurt am Main 2013.

7 Zhou K., Liu T., Zhou L., *Industry 4.0: Towards Future Industrial Opportunities and Challenges…*, op. cit., pp. 2147–2152.

4. Artificial intelligence - technologies enabling learning and solving complex problems by machines.
5. Cloud Computing - a set of computing technologies in which IT services are provided by cheap computing units connected by IP networks. [8]
6. Big Data - computational tools that enable data management anywhere and anytime, and provide data analysis connecting key areas of the company's operation[9].

Borghetti and others believe that by integrating advanced Industry 4.0 tools with digital technologies, manufacturing processes and systems are transformed in terms of decentralizing decision-making[10]. E. Płaczek emphasizes that "due to the availability of technology and flexibility in responding to market needs, the fourth industrial revolution should be perceived as an opportunity for development and increasing competitiveness"[11].

3. INDUSTRY 4.0 IN THE EUROPEAN UNION. RESEARCH RESULTS

Technological solutions of the broadly understood Logistics 4.0 constitute an element of the competitive advantage of enterprises on the market. This enables shortening the duration of production cycles, optimization of inventories, as well as lowering logistics costs, which in turn affects the loyalty of customers towards the company. The largest production companies around the world present the possibilities of implementing Logistics 4.0 innovations, among them - manufacturers from the automotive industry. Large companies invest in new technological solutions, justifying the purposefulness of their investments with greater process efficiency.

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8 Li S., Xu L. D., Zhao S., *The internet of things: a survey*, "Information System Frontiers, 17 (2015), pp. 243–259.

9 Woźniak J., Budzik G., Zimon D., *Industry 4.0 – identyfikacja technologii, które zmieniły przemysł oraz ich znaczenie w zarządzaniu logistycznym*, "Przedsiębiorczość i Zarządzanie", 19 (2018)/5, cz. 3, pp. 359-372; Ślusarczyk B., *Potencjalne rezultaty wprowadzenia koncepcji Przemysłu 4.0 w przedsiębiorstwach*, "Przegląd Organizacji", 948 (2019)/1, pp. 4-10.

10 Borghetti M., Cantù E., Sardini E., Serpelloni M., *Future sensors for smart objects by printing technologies in industry 4.0 scenario*, "Energies", 13 (2020)/22, 5916, pp. 1–15.

11 Płaczek E., *Logistyka w erze Industry 4.0…*, op. cit., pp. 55-66.

Previous studies have shown that the level of advanced technologies used in large companies is growing year by year, but the data from small and medium-sized enterprises may differ significantly compared to large companies. This can be represented by the digital intensity index - DII, which shows the degree of implementation of digital technologies in companies.

Therefore, according to the DESI 2020 report published by the European Commission, among all enterprises in the European Union employing over 10 people, 61% of enterprises have reached the basic level of the DII indicator (Fig. 1).

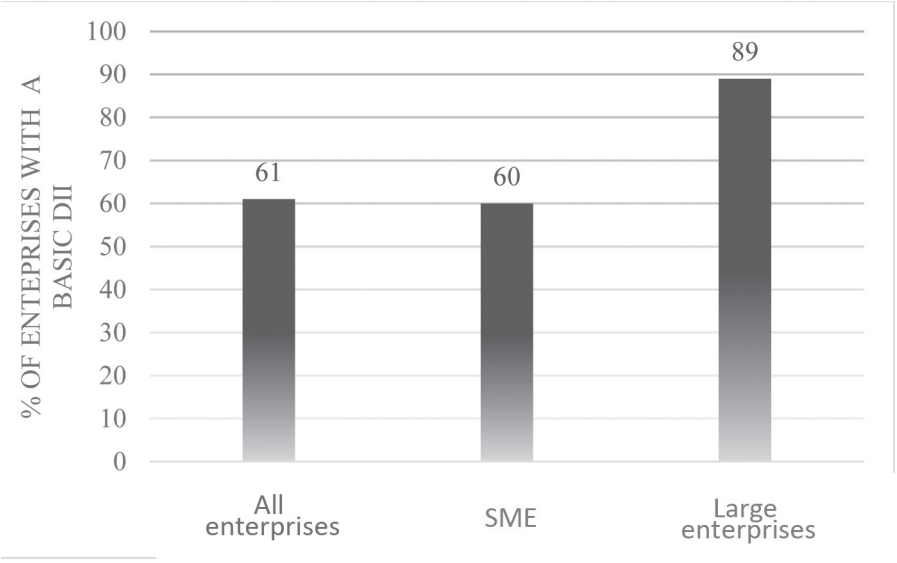

Fig. 1. Level of the DII index in European companies (2020)
Source: Eurostat.

Based on the analysis of the data contained in Figure 1, a large difference can be noticed between the DII level in the SME sector and in large enterprises. The data concerns enterprises operating in the territory of the European Union countries. According to the author, in large companies the level of application of modern technologies will always be higher than in smaller companies, because the development of the company and increasing the scale of operations may result in the necessity to introduce innovative solutions.

The level of DII in business in individual European Union countries varies significantly (Fig. 2).

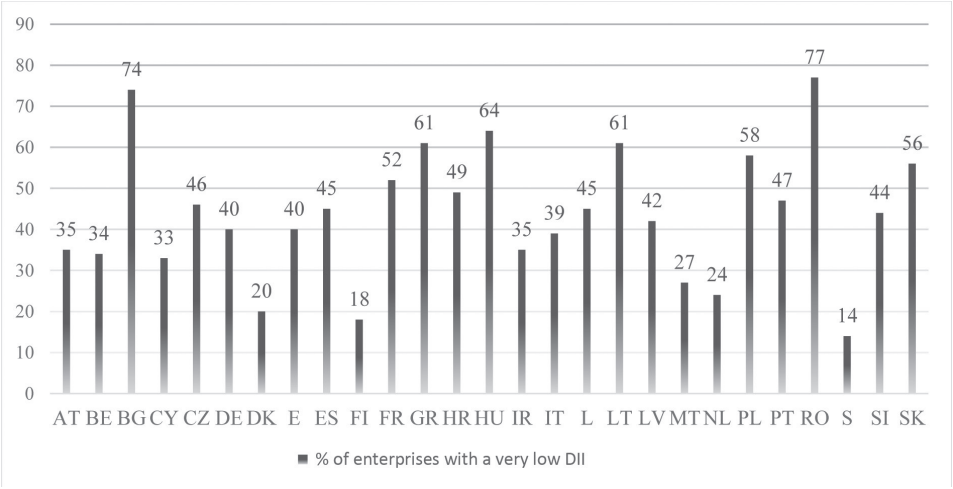

Fig. 2. EU countries with the lowest DII index in enterprises
Source: own study based on data from Eurostat.

The data from the figure above show that in 2020 as many as 77% of companies in Romania showed a very low level of the DII index, reportedly as in Bulgaria (74%). The lowest share of companies with a very low DII is noted in Denmark (20%), Finland (18%) and Sweden (14%).

In order to determine the current level of use of Industry 4.0 technologies and tools, statistical data from European Union countries were analyzed. The latest data is from 2021. Dynamically developing large enterprises have to a large extent already implemented Industry 4.0 technologies. This applies to both data processing and analysis, and to the use of robots and artificial intelligence in production processes (Table 1).

Tab. 1. The use of selected Industry 4.0 technologies in large companies in the EU in 2020-2021 (%)

EU country	Robots	Big Data	AI	3D printing	Cloud Computing	Internet of Things
Belgium	25	36	41	21	90	50
Bulgaria	18	12	15	7	45	26
The Czech Republic	34	14	24	26	62	55
Denmark	28	35	66	25	89	48
Germany	24	14	31	23	71	49
Estonia	16	17	21	8	81	36
Ireland	5	21	31	10	87	56
Greece	8	10	10	-	53	37
Spain	20	15	32	12	67	42
France	26	20	31	17	71	42
Croatia	17	16	22	8	68	42
Italy	22	16	24	15	83	59
Cyprus	3	15	13	7	85	43
Latvia	11	16	17	7	68	65
Lithuania	16	9	19	7	74	61
Luxembourg	16	15	39	13	69	46
Hungary	24	14	13	15	65	41
Malta	10	33	19	18	73	45
The Netherlands	17	28	41	11	87	39
Austria	29	17	32	22	75	74
Poland	28	16	17	17	70	51
Portugal	22	21	31	13	71	43
Romania	12	6	7	6	33	24
Slovenia	40	23	36	25	81	78
Slovakia	29	11	19	18	61	47
Finland	30	34	51	20	99	61
Sweden	24	20	40	20	94	61

Source: own study based on data from Eurostat

The data applies to all enterprises, except the financial industry

The data in Table 1 present the current state of use of Industry 4.0 technology in large enterprises (employing over 250 employees) in the European Union. Cloud Computing is the most commonly used solution in European companies. Among all large enterprises, at least half use a given technology in their activities (except Romania, where the value of this indicator is 33%). The second popular technology used by large European companies is the Internet of Things. The level of its use differs in individual EU countries, but the most companies use a given technology in Slovenia (78%), Finland and Sweden (61%), Latvia (60%), and the least - in Bulgaria (26%), and Romania (24%). It is also worth noting that among the surveyed group, the largest number of industrial robots is used in Finnish (16%) and Danish (24%) large companies. Finland and Denmark are also leaders in the European market in terms of the use of artificial intelligence in companies.

Tab. 2. The use of selected Industry 4.0 technologies in the SME sector in the EU in 2020-2021 (%)

EU Country	Robots	Big Data	AI	3D printing	Cloud Computing	Internet of Things
Belgium	7	6	9	6	52	26
Bulgaria	4	2	3	3	12	15
The Czech Republic	5	2	4	5	43	30
Denmark	9	6	23	9	64	18
Germany	4	3	10	7	41	34
Estonia	2	4	2	2	57	17
Ireland	0	5	7	2	58	33
Greece	-	-	4	-	22	22
Spain	6	2	7	5	30	25
France	6	3	6	4	28	21
Croatia	5	4	8	5	38	23
Italy	6	2	6	5	60	32
Cyprus	2	1	2	6	50	33
Latvia	2	2	3	2	28	26
Lithuania	3	2	4	3	32	27
Luxembourg	4	2	12	3	32	21

Hungary	3	2	3	3	25	22
Malta	4	9	10	8	57	27
The Netherlands	6	7	12	6	64	19
Austria	4	3	8	4	39	50
Poland	5	2	2	3	27	18
Portugal	6	2	17	4	34	21
Romania	3	1	1	1	14	10
Slovenia	7	3	11	4	42	49
Slovakia	5	2	5	3	35	26
Finland	7	8	15	7	75	38
Sweden	4	3	9	6	75	40

Source: own study based on data from Eurostat
The data applies to all enterprises, except the financial industry

European companies from the SME sector most often use two Industry 4.0 technologies - Cloud Computing and Internet of Things (IoT) (Table 2). The highest level of implementation of given technologies in small and medium-sized enterprises recorded in Finland and Sweden - 75% of the surveyed group use Cloud Computing and nearly 40% implement IoT in internal processes. Among the leaders in the use of artificial intelligence in small and medium-sized enterprises, it is worth mentioning Denmark (23%) and Portugal (17%). The use of service and industrial robots in the SME sector of individual European Union countries ranges from 2-9%. The lowest values among the studied group were observed in Romania, where artificial intelligence, Big Data and 3D printing were implemented in only 1% of small and medium-sized companies, and the use of IoT and Cloud Computing technologies does not exceed 14%.

Advanced digital technologies can drive growth, play a key role in market expansion as well as increase the competitiveness of companies. The analysis of the current state in the context of the implementation of Industry 4.0 technologies showed that the level of use of these technologies significantly differs in large companies and the SME sector. The reason for such a disproportion may be, first of all, the scale of activity. The use of industrial and service robots can be used to shorten the duration of individual operations in production processes, which will shorten production cycles as well as reduce costs. In small and medium-sized enterprises,

the increase in the level of robotization may be triggered by the planned increase in production.

An important element that has a significant impact on the level of advanced technologies in European companies can be investment in research and development by specific companies or a country as a whole. The companies involved in production, logistics and warehousing were selected for the analysis. The statistical data was reviewed, showing the number of enterprises that received R&D investments from national and local authorities in individual European Union countries. The availability of data from small and medium-sized as well as large enterprises varied depending on whether it is confidential or generally available information in a given country. The results of the analysis of the level of investments in small and medium-sized enterprises are presented in Fig. 3. It was found that in different Member States of the European Union the SME sector is characterized by a different structure of investment in research and development - in Austria, Belgium, Croatia, France, Italy and Spain more companies benefited from investments from local authorities, while in the case of Cyprus, the Czech Republic and Estonia, Finland, Germany, Malta and Sweden, there are more companies that received R&D investments from government. In the case of small and medium-sized enterprises, only 11.6% (maximum value) of companies benefited from R&D investments.

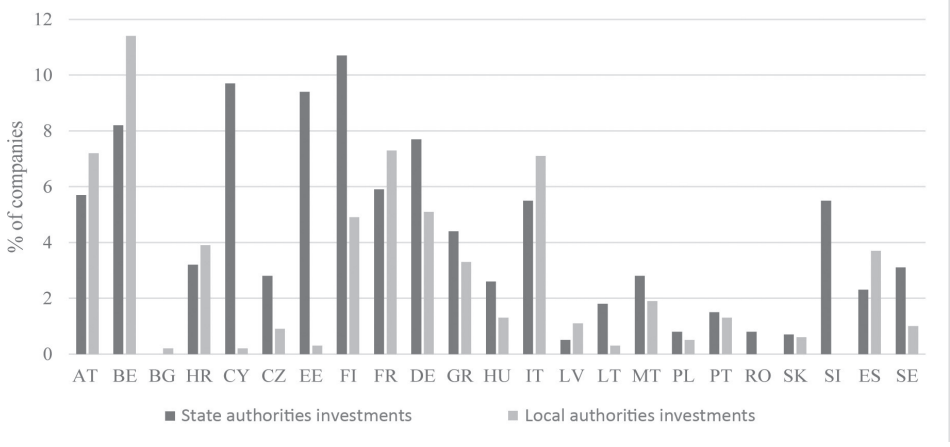

Fig. 3. The level of investments allocated to small and medium-sized enterprises for R&D (2021)
Source: own study based on data from Eurostat.

Compared to the SME sector, a much higher percentage of large companies received investment for research and development (Fig. 4). The largest companies in Belgium (64% of companies), Austria (59.3%) and Finland benefited from investments by state authorities. (48.7%). More than 30% of large companies in Austria and Belgium, approx. 20% in Sweden, and approx. 21% in Germany and France received investments from local budgets. The lowest values of the analyzed index are observed in Romania and Bulgaria.

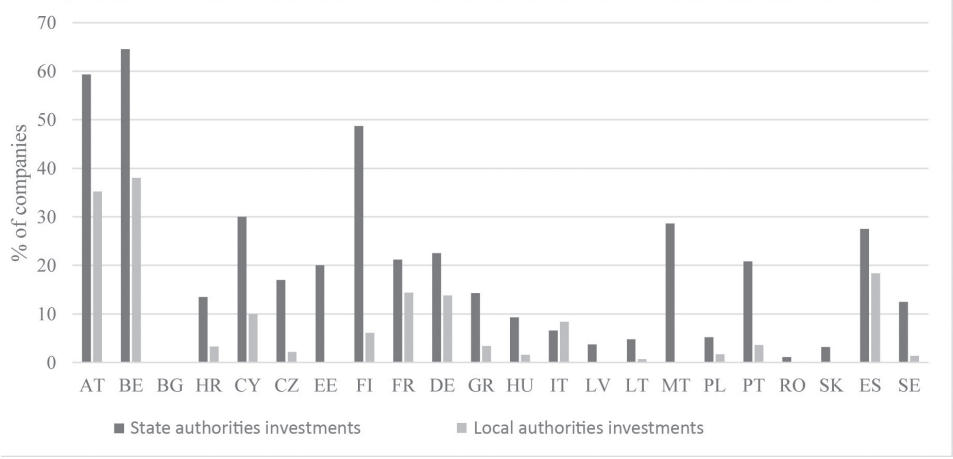

Fig. 4. The level of investments granted to large companies for R&D (2021)
Source: own study based on data from Eurostat.

Considering the level of implementation of digital technologies in the context of Industry 4.0, it can be suggested that one of the reasons for the low level of implementation of these technologies in Romania and Bulgaria may be the lack of state investment in R&D in a given sector. In addition, it is worth emphasizing that in the countries with the highest share of companies benefiting from R&D investments, a high level of use of technological innovations in the aspect of Industry 4.0 is recorded.

4. CONCLUSIONS

As a result of the research, it was found that there is a significant difference in the level of selected development of digital technologies in small and medium-sized as well as large enterprises operating in the European Union. Research has shown

that large companies employing over 250 employees use advanced technologies in the context of Industry 4.0 to a greater extent than companies from the SME sector. The author suspects that one of the reasons for such a phenomenon may be the diversified level of investments of local and state authorities in the research and development activities of these companies. After reviewing the statistical data, it can be concluded that the most developed countries in terms of the use of Industry 4.0 digital technologies are countries such as Denmark, Sweden and Finland. The lowest level of implementation of innovations in the context of Industry 4.0 and the lowest share of companies that benefited from state investment in research and development activities is recorded in Romania and Bulgaria. The aim of the research has been achieved. The hypothesis that large enterprises are characterized by a higher level of development of digital technologies than small and medium-sized enterprises has been confirmed.

REFERENCES

[1] Borghetti M., Cantù E., Sardini E., Serpelloni M., *Future sensors for smart objects by printing technologies in industry 4.0 scenario*, "Energies", 13 (2020)/22, 5916, pp. 1–15.

[2] Bujak A., *Rewolucja przemysłowa-4.0 i jej wpływ na logistykę XXI wieku*, "Autobusy: technika, eksploatacja, systemy transportowe", 18 (2017)/6, pp. 1338-1344.

[3] Eurostat.

[4] Kagermann H., Helbig J., Hellinger A., Wahlster W., *Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0: Securing the Future of German Manufacturing Industry*. *Final Report of the Industrie 4.0 Working Group*, Forschungsunion, Frankfurt am Main 2013.

[5] Lasi H., Fettke P., Kemper H.G., Feld T., Hoffmann M., *Industry 4.0*, "Business & Information Systems Engineering", 6 (2014)/4, pp. 239–242.

[6] Li S., Xu L. D., Zhao S., *The internet of things: a survey*, "Information System Frontiers, 17 (2015), pp. 243–259.

[7] Płaczek E., *Logistyka w erze Industry 4.0*, "Przedsiębiorczość i Zarządzanie", 19 (2018)/11, pt. 3, pp. 55-66.

[8] Ślusarczyk B., *Potencjalne rezultaty wprowadzenia koncepcji Przemysłu 4.0 w przedsiębiorstwach*, "Przegląd Organizacji", 948 (2019)/1, pp. 4-10.

[9] Weyer S., Schmitt M., Ohmer M., Gorecky D., *Towards Industry 4.0 – Standardization as the crucial challenge for highly modular, multi-vendor production systems,* "IFAC-PapersOnLine", 48 (2015)/3, pp. 579–584.

[10] Woźniak J., Budzik G., Zimon D., *Industry 4.0 – identyfikacja technologii, które zmieniły przemysł oraz ich znaczenie w zarządzaniu logistycznym*, "Przedsiębiorczość i Zarządzanie", 19 (2018)/5, cz. 3, pp. 359-372.

[11] Zhou K., Liu T., Zhou L., *Industry 4.0: Towards Future Industrial Opportunities and Challenges*, [in:] *12th International Conference on Fuzzy Systems and Knowledge Discovery, FSKD 2015, Zhangjiajie, China, August 15-17, 2015. IEEE 2015*, Zhangjiajie 2016, pp. 2147–2152.

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