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THE IMPACT OF INDUSTRY 4.0 ON THE DEVELOPMENT OF SMART CITIES - A SYSTEMATIC REVIEW OF THE LITERATURE

Abstract: *The aim of this paper is to analyze the impact that Industry 4.0 has on the development of smart cities as well as smart cities in general. In order to achieve this goal, a total of 373 scientific papers indexed in the Scopus database were included in the research, on the basis of which a systematic analysis, i.e. biometric analysis, was conducted. Based on the conducted analysis, it was identified that there is a change in trends related to the study of Industry 4.0 technologies and their impact on the development of smart cities. It should be emphasized that Industry 4.0 technologies have a significant impact on the transformation of traditional cities into smart cities. This research provides insight into previous research by authors in this field and assessment of future trends related to the development and impact of Industry 4.0 on smart cities.*

Keywords: *Smart cities; Sustainability; Industry 4.0; Biometric study*

1. Introduction

Industry 4.0 is first mentioned in the context of the German Development Strategy from the year 2011 (Alcácer and Cruz-Machado, 2019) and implies the digitalization of business, i.e. the application of digital solutions in process management automation (Culot et al., 2020). Parallel with the development of Industry 4.0, new concepts and new technologies are emerging, such as the Internet of Things, big data, cloud computing, 3D printing, augmented reality, and virtual reality (Dubey et al., 2022). In addition, with the development of Industry 4.0, there is also a need to increase sustainability because changes in environmental, social and economic environment lead to inequality. Furthermore, above mentioned leads to emphasizing the importance of sustainable development by the United Nations by de-fining 17 sustainable development goals (Bose and Khan, 2022). Particularly important areas covered by the sustainable development goals are cities and urban areas through UN goal 11 directly, while through other goals indirectly since urban areas are centres of consumption of energy, products and other resources, which directly affects (un)sustainability if resource consumption is excessive or uncontrolled (Liu, 2020). In other words, if the sustainable development goals are considered in more detail, the goals related to the sustainability of the urban area can be reduced to the responsible con-sumption of resources, quality education, availability of health care, available and clean energy, clean water and sanitation. This is particularly important for urban areas with large population and where large population is the reason for the often-uncontrolled consumption of resources. To

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achieve the sustainable development goals defined by the UN, one of the mechanisms that can be used is Industry 4.0 technologies (Khan et al., 2021). In other words, the automation and implementation of Industry 4.0 technologies can improve the efficiency of using a natural resource, increase energy efficiency and reduce waste and greenhouse gas emissions during production (Javaid et al., 2022). The use of technologies such as the Internet of Things in transport, i.e. traffic management, creates a basis for reducing emissions, as it seeks to reduce traffic congestion and thus related pollution (Zhao et al., 2022). Based on this, the implementation of technologies that enable automation, i.e. increasing energy efficiency, and reducing the negative impact that the urban area has on the environment results in the creation of smart cities.

However, the notion of smart cities today differs from the notion of smart cities in the past. In the past, smart cities have meant urban planning that will provide all residents equal opportunities, i.e. reduce inequality. In addition, before the concept of smart cities appeared, in the 1950s developed term sustainable cities emphasised the need to define strategies to reduce the negative impact of cities on climate change. Furthermore, in the 1990s, the concept of digital cities appeared, which refers to the digitalization of processes that take place in cities, while in 2009, the concept of smart city was developed (Eremia et al., 2017). Further development of the concept of smart cities is arising with the emergence of Industry 4.0 and technologies that are being developed within Industry 4.0, which affect the functioning of processes in urban areas.

In other words, smart cities and the concept of smart cities have changed throughout history and have been significantly shaped by the emergence of Industry 4.0 and the UN-defined sustainable development goals of reducing the negative impact of urban areas on the environment and resources consumption which is especially important when talking about the growing number of inhabitants living in urban areas. The increase in the number of inhabitants in urban areas brings with it challenges related to providing enough resources that are necessary for the normal functioning of processes in urban areas, but also reducing the possible negative impact of such processes.

Given the importance of smart cities, an increasing number of authors are beginning to see the importance of smart cities in ensuring sustainability (Trindade et al., 2017; Treude, 2021; Evans et al., 2019), or the impact that Industry 4.0 has on increasing and developing sustainability (Bai et al., 2020; Ghobakhloo and Fathi, 2021). In their research, the authors look at how Industry 4.0 technologies affect logistics operations and the development of logistics operations in urban areas (Korczak and Kijewska, 2019) and how Industry 4.0 technologies can affect supply chain management (Tjahjono et al., 2017). It was identified that the authors consider the impact that Industry 4.0 has on various areas such as logistics, supply chain, and the possibility of applying Industry 4.0 technologies in production to automate and increase the efficiency of production processes (Büchi et al., 2020) and transport processes, especially ongoing processes in rail transport (Gerhátová et al., 2021). In other words, the authors look at how Industry 4.0 technologies affect different subsystems that are part of a larger system, such as an urban system. However, given the fact that Industry 4.0 have an impact on the development of smart cities and smart cities have an impact on achieving the goals of sustainability and sustainable development which have been identified through the analysis of sustainability goals defined by the UN, there is a need of analysis of the impact that Industry 4.0 has on the development of smart cities.

Regarding that, in this paper, a systematic review of the literature based on biometrics on the impact that Industry 4.0 has on the development of smart citiesis conducted.

Biometrics is a method used in the analysis of many sources, i.e. papers to identify the development of the analyzed area, i.e. to identify the trend that is present in the analyzed area (Donthu et al., 2021). Software packages such as R have been developed for conducting analysis using biometrics, which enables the analysis of many articles and insight into research trends based on the conducted analysis. The results of the analysis can be presented using graphs or tables, which can show the citation of works, the productivity of authors, the productivity of institutions from which authors come or the like. In addition, biometrics eliminates the potential subjectivity that the researcher has when conducting research, which is why the results obtained based on biometrics can be the basis for future research or the work of other authors (Sombultawee et al, 2022).

This paper presents a systematic review of the literature in the field of the impact of Industry 4.0 on the development of smart cities. The following research questions were asked in the paper:

- What is the impact of Industry 4.0 on the development of smart cities?
- Which Industry 4.0 technologies have the most significant impact on the development of smart cities?

The paper is divided into chapters. The first chapter introduces the development of Industry 4.0 and the impact that Industry 4.0 has on sustainability and sustainable development. The second chapter describes the materials and methods, i.e. the methodology based on which the research was conducted. The third chapter refers to the description of the research results, while the fourth chapter discusses the obtained results. The fifth chapter is the concluding chapter, which defines the limitations and recommendations for future researchers in this field.

2. Materials and Methods

2.1. Research methodology

The research was conducted by searching the SCOPUS database with the keywords "Industry 4.0" and "smart cities". The search includes all works in the period from year2016 to the year 2022. When searching, search parameters include titles of papers, abstracts, or keywords. Papers considered when searching are all papers regardless of language or country, or author. The initial search of the SCOPUS database identified 456 papers, after which the results were filtered exclusively on professional and scientific articles, i.e. papers published in the proceedings, and the results related to books were excluded. Based on filtering, out of a total of 456 initial papers, the number of papers was reduced to 373 which is the basis for conducting research (figure 1).

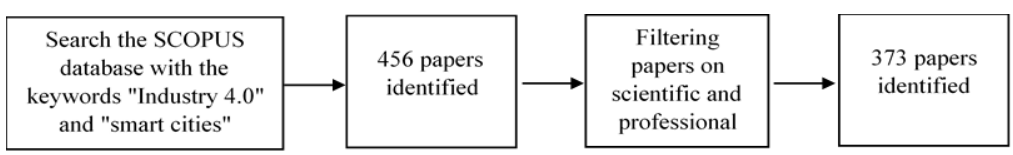

Figure 1. Research methodology

The R programming language with the addition of biometrics was used to analyze the obtained results. R is a programming language for quantitative research that uses the biometric add-on to provide a systematic review of the literature, i.e. the productivity of authors, the productivity of countries, citations, the number of published papers in journals and the like.

2.2. Biometric study

Based on the selected 373 papers, an analysis was conducted which includes analysis of authors' productivity, analysis of countries' productivity, analysis of institutions' productivity, analysis of papers, analysis of sources in which papers were published, analysis of authors' citations, analysis of authors' cooperation and keyword analysis.

The analysis of the author's productivity is based on the number of papers published by authors in the observed period from 2016 to the 2022, the country from which the authors with the largest number of papers come, the share of the author in the total number of papers, Articles Fractionalized for each from the author and h index of authors. Based on the analysis of the author's productivity, one can come to the knowledge of the author who has the largest number of published papers, i.e. the author who has the greatest contribution to the development of the observed area.

When analyzing the productivity of countries, the parameters considered are the number of papers produced in the country, the total number of citations for the area of impact of Industry 4.0 on the development of smart cities and average article citations. In addition, when analyzing the productivity of countries, the obtained results are presented graphically using a map of the world and a table where the table describes the described parameters. Furthermore, it should be noted that the graphical representation of the productivity of countries shows the productivity of the country by colour, i.e. the darker the colour the more work the country has and vice versa. Based on the analysis of the productivity of countries, one can come to an understanding what countries have the greatest impact on the development of the observed area.

The analysis of the productivity of institutions is based on the analysis of the number of papers related to the institution. During the analysis, in addition to the number of papers related to the institutions the country in which the institution is located is also stated. With the help of the productivity analysis of institutions, it is possible to identify the institutions that have the greatest impact, i.e. they are mostly engaged in the study of the area of Industry 4.0 and smart cities.

The analysis of papers was conducted based on Normalized TC that refers to the total number of citations related to each paper, the total number of citations through the year when the reference year is the year in which the paper was published. From the total number of papers included in the analysis, 10 papers with the largest number of citations were selected. Papers are arranged by the number of citations from the paper with the highest number of citations to the paper with the lowest number of citations.

Source analysis includes the analysis of the number of published papers in journals or conferences, where the parameters are the number of published papers, an h-index of the journal in which the paper was published and the impact factor for each of the journals. Out of the total number of journals in which papers were published, 10 journals with the largest number of published papers were considered during the analysis.

The analysis of mutual citations of authors implies the analysis of citations of individual papers, i.e. the impact that each paper has on the research described in other papers. In the analysis of mutual citations, the papers were divided into clusters marked with different colors. All clusters are interconnected by lines, and the thickness of the line indicates the number of citations. In other words, the higher the number of citations, the larger the line connecting the clusters and vice versa. Based on the analysis of mutual citations, the paper that has the greatest impact on the research of other authors can be identified.

The analysis of the authors' cooperation is presented using clusters that have different colors and are interconnected by lines. The

thicker the line connecting the clusters, the greater the cooperation between the authors, i.e. the more the authors cooperate with each other. Based on the analysis of cooperation, the institution where the author's work can be identified, i.e. cooperation between different authors from different institutions can be analyzed.

Keyword analysis refers to the analysis of the most frequent keywords used in the analyzed papers, as well as the change in the use of keywords over time. A keyword analysis is presented using a dendrogram, i.e. a table where the frequency of each keyword and the percentage are tabulated, while the dendrogram shows the relationship between different keywords that are classified into categories. Based on the analysis of keywords, it is possible to identify the focus of papers, i.e. trends in research, as well as to make recommendations for future research regarding the changes that have been identified.

3. Results

The results of the research indicated an increased interest among researchers on the impact of Industry 4.0 on the development of smart cities.

Figure 2 shows the productivity of authors in the observed period from 2016 to the 2022, which shows that there is an increase in the interest of researchers in this field, but during 2021 there was a slight decline in the number of papers. It should be emphasized that the data for 2022 are not fully available since the whole of 2022 was not analyzed, but only the first quarter.

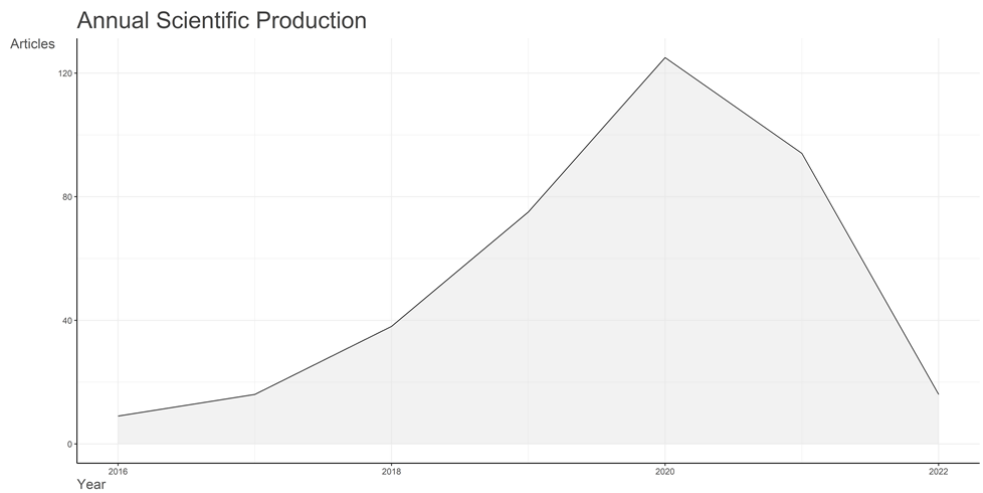

Figure 2. Annual Scientific production

When it comes to citation analysis, Figure 3 shows the average citation in the period from 2016 to the 2022. The chart shows that the average citation rate of the research decreased after 2017, but during 2019 there is an increase in the number of average citations. However, the stagnation of citations continues, and at the end of 2021, there is an increase in the number of average citations of papers. If the cooperation of authors is analyzed, out of the total number of papers, 12.33% of papers were produced by international cooperation of authors, while the average number of authors per work is 3.82. Papers published in the observed period have been cited an average of 8,021 times, while the average growth rate of the number of papers in the observed period was 10.06%.

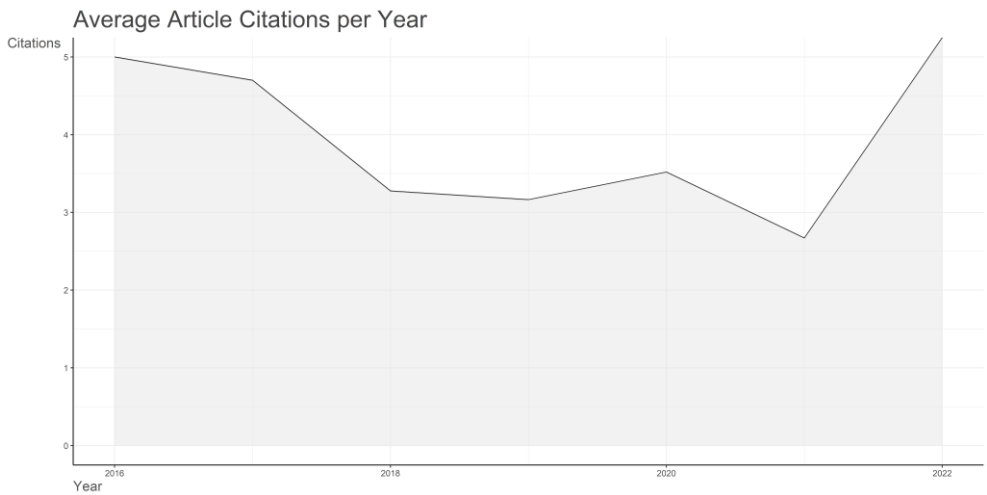

Figure 3. Average article citations per year

3.1. Author productivity

Table 1 shows the productivity of authors, the author's country, the number of papers that authors have published, articles fractionalized and the h-index for each of the authors. Table 1 shows that the first four authors have the same number of works, namely Zheng Liu (Canada), Theodore E. Matikas (Greece), Anastasios C. Mpalaskas (Greece) and Miroslav Svítek (Czech Republic). The fundamental difference is that Miroslav Svítek has Articles Fractionalized 2.00 in comparison with other authors.

Table 1. The most productive authors

Rank	Authors	Country of Author	Articles	%	Articles Fractionalized	h-index
1.	Zheng Liu	Canada	4	1,07	0.49	37
2.	Theodore E. Matikas	Greece	4	1,07	1.42	37
3.	Anastasios C. Mpalaskas	Greece	4	1,07	1.42	10
4.	Miroslav Svítek	Czech Republic	4	1,07	2.00	25
5.	Daniel G. Costa	Brazil	3	0,80	0.95	19

If we look at the author's h-index, the authors with the highest h-index are Zheng Liu with a h-index of 37 and Theodore E. Matikas with a h-index of 37, followed by Miroslav Svítek with a h-index of 25 and Daniel G. Costa with a h-index of 19.

3.2. Country productivity

Table 2 shows the most productive countries in the context of professional and scientific papers.

The table shows that the country with the largest number of produced papers is China (68 papers), followed by Spain (51 papers) and India (48 papers). Looking at the total number of citations per country, the country with the highest number of citations is Italy (381 citations), followed by the United Kingdom (348 citations) and China (337 citations).

Table 2. The most productive authors in the observed period

Rank	Region	Freq	Citations	Average article citations
1	China	68	337	17.74
2	Spain	51	207	11.50
3	India	48	55	9.17
4	USA	45	94	6.27
5	Brazil	43	3	0.75
6	Germany	41	25	4.17
7	Italy	41	381	47.62
8	UK	30	348	47.62
9	Indonesia	24	5	2.50

Furthermore, looking at the average citation rate, Table 2 shows that the two countries have the same number of averages citations, i.e. Italy and the United Kingdom with 47.62 average citations per paper, followed by China with 17.74 average citations per paper and Spain with 11.50 average citations by paper.

Figure 4 shows the distribution of published papers worldwide. The higher the number of papers per country, the colour of the country is darker and vice versa. In North America, the dominant country producing the largest number of papers is the USA, in South America Brazil, while in Europe a high concentration of papers was produced in Spain, Germany, Italy and Poland, and the United Kingdom has equal representation. In the East, i.e. in Asia, India and China stand out as two countries that are equally represented. Other countries shown in the colours on the map on Figure 2 are less represented in the total number of published papers, i.e. the countries shown in grey do not have any papers in the sample of selected papers for analysis. Based on the analysis, it can be identified that on each continent there are one or more countries that study smart cities, i.e. Industry 4.0 technologies and the impact on smart cities, which indicates the importance of this area.

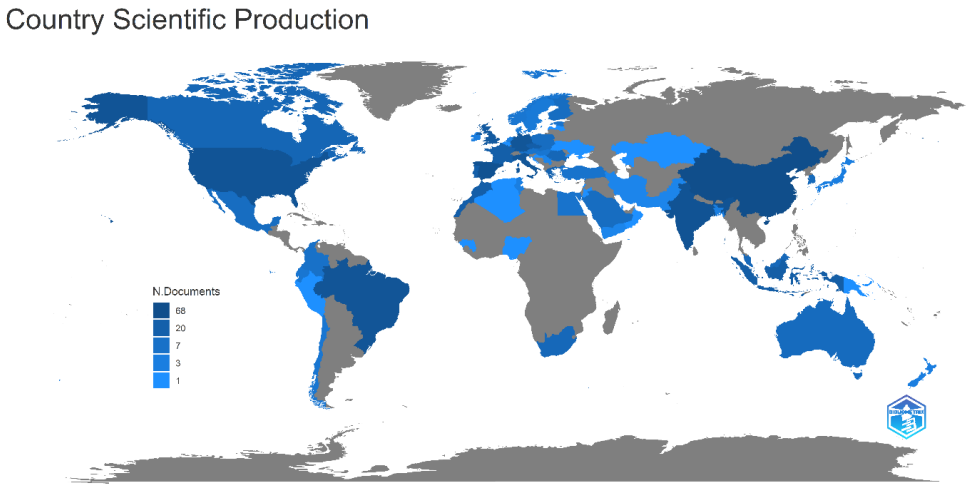

Figure 4. Overview of the prevalence of works in the world

3.3. Productivity of institution

Table 3 shows the most productive institutions. The list of the most productive institutions provides insight into the specialization of institutions in terms of Smart City, as well as specialization related to the consideration of possible impacts that Industry 4.0 has on the development of Smart City. Table 3 shows that the largest number of papers comes from the University of Aveiro (Portugal), i.e. of the total number

of papers considered is 7. The same number of papers have the University of Johannesburg (South Africa) and the University of São Paulo (Brazil). In the relative share, all the listed countries have a share of 0.94%. However, most institutions have one article or almost 80% of them.

Table 3. Institutional Productivity Analysis

Affiliations	Country	Articles
University of Aveiro	Portugal	7
University of Johannesburg	South Africa	7
University of São Paulo	Brazil	7
Tallinn University of Technology	Estonia	6
Not reported		5
UniversitiTeknologi Mara	Malaysia	5
University of Brescia	Italy	5
Czech Technical University in Prague	Czech Republic	4
Jouf University	Saudi Arabia	4
University of catania	Italy	4

It is important to note that there are five papers in the field of the impact of Industry 4.0 on the development of smart cities for which no author institutions are defined, which can be interpreted as papers created within city institutions, i.e. researchers who are not employed at universities but work in other institutions.

3.4. Analysis of papers

The analysis of papers presented in Table 4 indicates the papers that are most cited in the observed period, i.e. shows the papers that other authors use as one of the bases in their research. "Fog of everything: Energy-efficient networked computing architectures, research challenges, and a case study" by Baccarelli, Naranjo, Scarpiniti, Shojafar and Abawajy stands out as the work with the largest number of citations. In this paper, the authors consider two new paradigms that emerge with the development of Industry 4.0 more precisely Fog computing and the Internet of everything. Authors are analyzing how the mentioned paradigms will affect the development of smart cities and other technologies of Industry 4.0 such as the Internet of Things, big data, and the like. The paper has a total of 224 citations, i.e. an average of 37.33 citations per year with a normalized total citation of 9.5319.

The second paper that has the largest number of citations is "Digital twin: Enabling technologies, challenges and open research" by Fuller, Fan, Day and Barlow. In the paper, the authors look at the impact that digital twins' technology has, as well as describe the challenges and opportunities of connecting digital twins with artificial intelligence and the Internet of Things. The paper has a total of 172 citations with an average citation per year of 57.33 and normalized total citations of 24.4318. In the third paper, which recorded the largest number of citations, the "Digital twin five-dimensional model and its application in ten fields" by Tao, Liu, Zhang, Hu, Qi, and Zhang, the authors describe the possibilities of using digital twins technology in various fields such as vehicles, power plants, complex equipment used in medicine, smart cities, and similar. The paper has a total of 144 citations with an average number of citations per year of 36, or normalization total citations in the amount of 15.1685.

Looking at the papers shown in Table 4 and the content or topics of the papers, it can be identified that most papers talk about the possibilities of artificial intelligence and digital twins in areas of complex systems such as the city. Special emphasis was placed on the impact that Industry 4.0 has on the development of smart cities, i.e. on the opportunities that the implementation ofIndustry 4.0 technologies has on the management of smart cities.

Table 4. Papers that recorded the highest number of citations

Rank	Paper	Authors	TC	TC per Year	Normalized TC
1.	Fog of everything: Energy-efficient networked computing architectures, research challenges, and a case study	Baccarelli, E., Naranjo, P. G. V., Scarpiniti, M., Shojafar, M., &Abawajy, J. H.	224	37.333	9.5319
2.	Digital twin: Enabling technologies, challenges and open research	Fuller, A., Fan, Z., Day, C., & Barlow, C	172	57.333	24.4318
3.	Digital twin five-dimensional model and its application in ten fields	Tao, F., Liu, W. R., Zhang, M., Hu, T. L., Qi, Q. L., & Zhang, H.	144	36	15.1685
4.	Industry 4.0 as a part of smart cities.	Lom, M., Pribyl, O., &Svitek, M.	134	19.143	4.4667

3.5. Source analysis

Source analysis is used to identify the source, i.e. the journal in which the largest number of papers in the field of the impact of Industry 4.0 on the development of smart cities is published. Citations, journal h-index, journal impact factor, and the number of papers published in the journal were used as parameters used for the analysis. Proceedings of the SPIE conference organized by the International Society of Optics and Photonics are identified as the source with the highest number of published papers. If the sources are viewed from the aspect of the h-index, the source with the largest h-index is Lecture Notes in Computer Science with an h-index of 400, followed by Proceedings of SPIE - The International Society for Optical Engineering with an h-index of 176 and the third site is IEEE Access with an h-index of 127.

Furthermore, if we look at the impact factor for the sources shown in Table 5, the source with the highest impact factor is the IEEE Internet of Things Journal with an impact factor of 12.37 followed by Future Generation Computer Systems with an impact factor of 9.11 and in third place IEEE access with an impact factor of 3.37.

Table 5. Sources with the largest number of published papers

Sources	h-index	Implact factor	Articles
Proceedings of SPIE - The International Society for Optical Engineering	176	0.45	27
Procedia computer science	76	2.09	14
Advances in Intelligent Systems and Computing	41	0.63	11
IEEE access	127	3.37	9
ACM International Conference Proceedings Series	123	0.61	8
CEUR Workshop Proceedings	52	0.55	6
Lecture Notes in Computer Science	400	1.36	5
Sustainability (Switzerland)	85	3.25	5
Future Generation Computer Systems	119	9.11	4
IEEE Internet of Things Journal	97	12.37	4

3.6. Co-citation

The co-citation of authors provides insight into the cooperation between authors, i.e. clusters dealing with different areas of

research related to the impact of Industry 4.0 on the development of smart cities. Figure 5 shows the citations of the authors, and from Figure 2 it can be identified that there are six clusters that are interconnected.

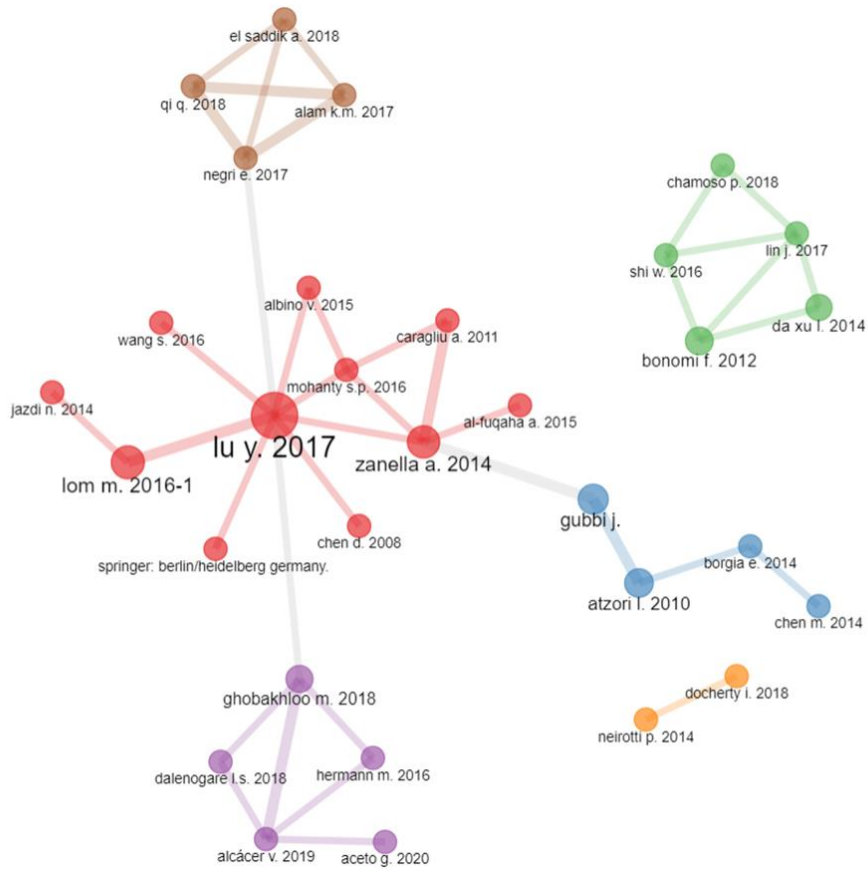

Figure 5. Mutual citation of authors

The most cited paper in the red cluster is "Industry 4.0: A survey on technologies, applications and open research" by Yang Lu with a number of recorded citations of 2277. Yang Lu is also the most influential author in the red cluster based on the research of other authors, and primarily the paper"Industry 4.0 as a part of smart cities" by Lom, Pribyl and Svitek who talk about Industry 4.0 as components of all smart cities, and which recorded 252 citations. In their work, Lom, Pribyl and Svitek describe Industry 4.0 technologies such as the Internet of Energy, the Internet of Services and similar, on the development and functioning of smart cities. In addition to the above, in the Red Cluster is identified that the third most important paper is produced by Zanella, Bui, Castellani, Vangelista and Zorzi, who, like Lom, Pribyl and Svitek, describe the impact of the Internet of Things on functioning and development of smart cities. The work of Zanello, Bui, Castellani, Vangelista and Zorzi recorded a total of 3253 citations. If we look at the connection with other clusters, Zanella, Bui, Castellani, Vangelista and Zorzi are the link with the blue cluster, while Yang Lu is the link with the brown and purple clusters.

In the blue cluster, as the author, i.e. the paper with the largest number of citations, stands out the "Internet of things: A survey" by Atzori, Iera and Morabito, which recorded a total of 17,221 citations. In this paper, the authors see the potential for the development of Internet of things technology as a new paradigm that will enable better functioning of the system, or the creation of so-called SMART systems which, as a fundamental feature, have the possibility of mutual communication, i.e. exchange of information. The paper laid the foundation for the research of other authors in this field, but also for the development and reflection on the potential that the Internet of Things has. Among other authors in the blue cluster, the work of Jayavardhan Gubbi stands out, who, like other authors, analyzes in his paper the potential and development of Internet of things technology in the context of managing complex systems.

When discussing the authors from the purple cluster, the most cited author, who is also the link with the red cluster, is Morteza Ghobakhloo with the paper "The future of manufacturing industry: a strategic roadmap towards Industry 4.0" in which author describes the impact of Industry 4.0 as a phenomenon on the development of the manufacturing industry. The paper has recorded a total of 767 citations, and the author in it, in addition to describing Industry 4.0 as a phenomenon, describes fourteen basic technological trends that occur with the advent of Industry 4.0, or design principles that emerge with changes and the emergence of Industry 4.0. Vitor Alcácer and Cruz-Machado Virgilio stand out as the authors who continue research based on paper of Morteza Ghobakhloo. The paper has been cited a total of 633 times, and the authors describe how Industry 4.0 and the technologies that emerge with the development of Industry 4.0 have a significant impact on the emergence of disruption and disruptive models that can form the basis for developing competitive advantage.

In the brown cluster, authors who stand out the most for the number of citations is Negri, Elisa, Luca Fumagalli, and Marco Macchi with paper "A review of the roles of digital twin in CPS-based production systems". The paper recorded a total of 252 citations, and the authors consider the impact of digital twin's technology and cyber physical system in factories and production. The authors consider the possibility of interconnection of the mentioned technologies and the advantages of their inter-connection in the context of creating smart factories. The mentioned work and the authors are also a link with the red cluster.

The green cluster and the papers within the green cluster are not related to other clusters. However, an author and paper that stands out, particularly within this cluster is Bonomi, Flavio with his paper "Fog computing and its role in the Internet of Things" which recorded a total of 6297 citations. In the mentioned paper, the author describes the characteristics of fog computing as a component of cloud computing and states as advantages the geographical spread, the large number of nodes involved in the network, heterogeneity and similar characteristics. Bonomi, Flavio laid the foundations for the research of other authors from the Green Cluster, of which Da Xu, Li, Wu He, and Shancang Li stand out as particularly significant. The paper "Internet of Things in Industries: A survey" that has a total of 4636 citations is the next most important. Da Xu, Li, Wu He, and Shancang Li. S describe the Internet of Things as an opportunity to de-velop extremely significant systems expressed in industry and industrial systems and conduct research aimed at identifying the current situation regarding the possibilities of applying the Internet of things technology.

Two significant papers have been identified in the orange cluster, one by Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G., and Scorrano, F. entitled "Current trends in Smart City initiatives: Some stylized facts", which recorded a total of 2167 citations. The

authors consider the first significant attempts to create smart cities, i.e. analyze the areas affected by the transformation of traditional cities into smart cities, i.e. emphasize the importance of developing a smart city strategy as a basis for transformation. Another important paper from the orange cluster is "The governance of smart mobility" by Docherty, Iain, Greg Marsden, and Jillian Anable, who analyze mobility management in the context of a smart city, i.e. the concept of smart mobility in the context of autonomous vehicles, Internet of things technology and similar.

The analysis of clusters and the most significant papers in clusters identified how the authors of papers from the beginning of Industry 4.0 development mostly talk about the possibilities of applying different technologies that occur as a result of Industry 4.0 development, and primarily the application of Internet of things technology in transforming traditional cities into smart cities.

All authors in the papers come to know about the possibilities that the implementation and application of Industry 4.0 technologies have and connect with each other except in the case of green and orange clusters that are not related to other clusters.

3.7. Collaboration network

Figure 6 shows the collaboration network. The collaboration network can be used in the analysis of cooperation between different authors in the field of the impact of Industry 4.0 on the development of smart cities. The size of the circle indicates the number of papers produced by the authors, and the thickness of the connection between the circles indicates the collaboration between the authors. The larger the size of the circle, i.e. the thicker the connection between the circles, the greater the cooperation between the authors and vice versa.

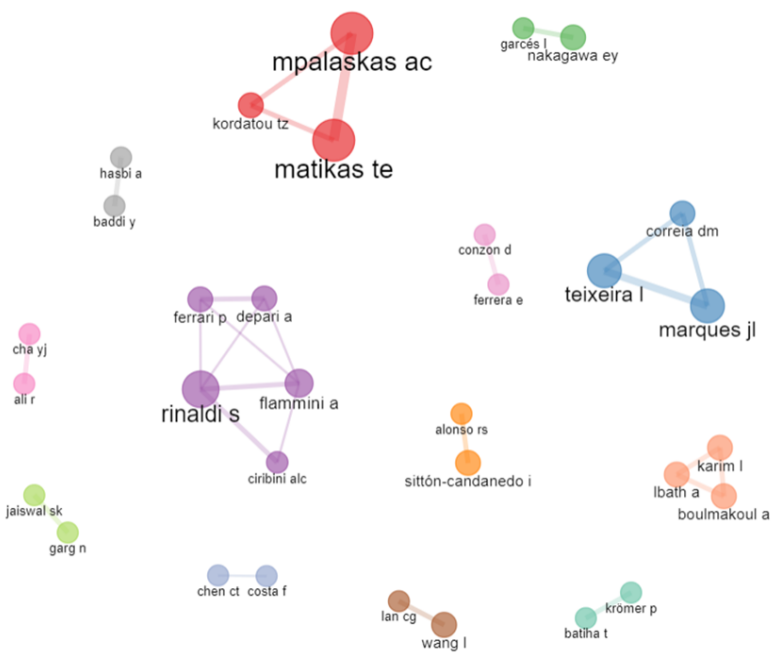

Figure 6. Collaboration network view

Figure 6 shows that none of the clusters are connected to the other cluster, each cluster functions for itself, which indicates a lack of cooperation between clusters. However, the purple cluster Stefano Rinaldi (Italy), which brings together associates Alessandra Flammini (Italy), Ferrari Paolo (Italy), Alessandro Depari (Italy) and Ciribini, Angelo Luigi Camillo (Italy), is particularly clustered.

On the other hand, in the red cluster, Theodore E. Matikas (Greece) and Anastasios C. Mpalaskas (Greece) stand out as the two most important authors, joined by Theodoti Z. Kordatou (Greece).

In the blue cluster, the most important authors are Leonor Teixeira (Portugal) and Joao Lourenço Marques (Portugal) joined by Diogo Mendes Correia (Portugal).

It is evident from the conducted analysis that authors who cooperate with each other are also authors who are from the same countries, i.e. work at the same institution. Authors from the European countries, i.e. the European Union are cooperating with each other, while all other authors are less represented, i.e. less cooperating in the preparation of papers and research.

3.8. Keyword Analysis

Keyword analysis provides insight into the keywords that authors use in their papers. Using keyword analysis, it is possible to identify research trends as the possible existence of gaps in research. Table 6 shows the keyword analysis for the analyzed area. The total number of identified keywords is 2855, of which the keyword with the highest frequency is Industry 4.0 with a total of 150 impressions, which represents 13% of the total number of keywords, followed by Smart City with a total of 137 appearances representing 12%. The third keyword is the Internet of Things with a total of 126 occurrences or a share of 11%.

Table 6. Keyword Analysis

Words	Occurrences	%
Industry 4 0	150	13%
Smart city	137	12%
Internet of things	126	11%
Embedded systems	49	4%
Internet of things (iot)	30	3%
Internet of thing (iot)	29	3%
Automation	26	2%
Industrial revolutions	22	2%
5g mobile communication systems	21	2%
Cyber physical system	21	2%
Decision making	21	2%
Artificial intelligence	20	2%
Nondestructive examination	19	2%
Big data	18	2%
Intelligent buildings	18	2%
Network architecture	18	2%
Network security	18	2%
Digital storage	17	2%
Digital transformation	17	2%
Blockchain	15	1%

Figure 7 shows a dendrogram indicating the hierarchical order and relationships between the keywords identified during the analysis. The dendogram defines and assigns weight to each item included in the cluster and analyzes, i.e. measures, the relationship between items. In other words, Figure 7 shows the two clusters and the keywords arranged within them. The first cluster (red) talks about the technological preconditions that cities must provide for the technologies used for transformation shown in the blue cluster to be used. In other words, the city must ensure the possibility of achieving interoperability, which is a prerequisite for the implementation of technologies such as the Internet of Things, big data, artificial intelligence and the like. In addition, the possibility of ensuring interoperability must include security, as security is of importance when it comes to the possibility of applying transformation technologies, as otherwise

there will be a risk of unauthorized access to information, or the risk of taking over management.

Furthermore, in addition to the analysis of the relationship between keywords, an analysis of trends in the occurrence of keywords during the period from 2016 to 2022 was conducted. The analysis is shown in Figure 5. Based on Figure 8, it can be seen that at the beginning of 2016 the keyword "Internet" was used the most, after which in the period from 2016 to 2018 the interest of researchers related to computer systems began to increase the keyword "distributed computer systems", i.e. product development and design (keyword "product design") and finally technologies related to the application of computers themselves (keyword "computing technology").

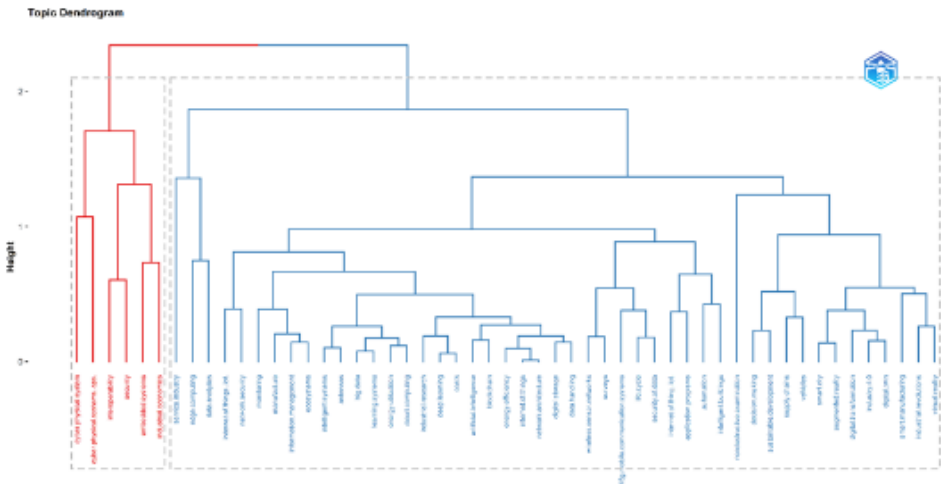

Figure 7. Keyword dendogram

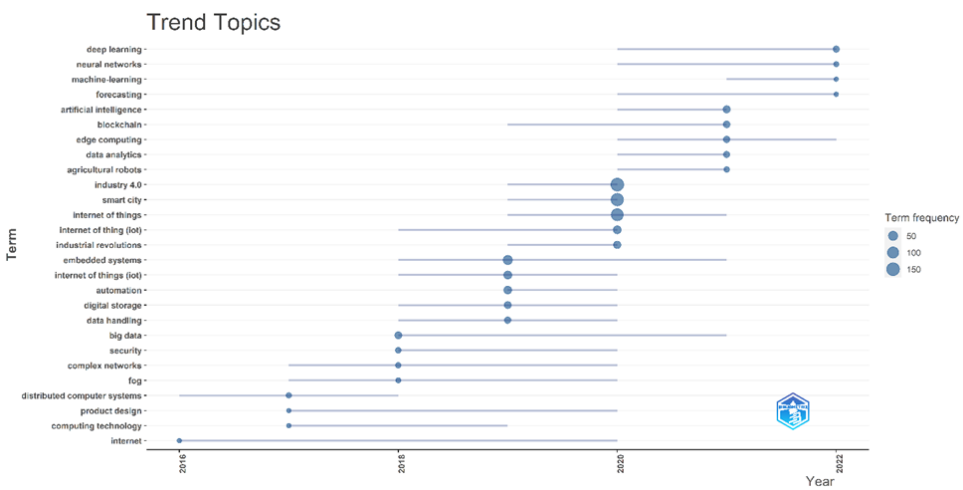

Figure 8. Analysis of keyword usage trends

In 2018, there is a focus of researchers related to data, primarily big data, which is also the most used keyword in that period, followed by the keywords "security", "complex network" and "fog" that can be associated with collecting, processing, i.e. storing once collected in-formation.

Furthermore, in 2019, keywords related to automation and data management appear, i.e. "day handling", "digital storage", "automation", "Internet of things" and "embedded systems". Looking at the connection between the mentioned keywords, it can be identified that the focus of researchers in this period is the analysis of the possibilities of managing the system through the Internet of Things technology and using the collected data. Research conducted in 2019 is also the basis for research that ap-pears in 2020, which begins to consider the possibilities of applying Industry 4.0 in the development of smart cities and the possibilities of using the Internet of Things as one of the technologies that can be used in smart city development. This is evident from the keywords used by the authors in that period, namely “Industry 4.0”, “Smart City” and “Internet of Things”.

Furthermore, in 2021, researchers focus on the application of artificial intelligence, data analysis, and application of blockchain technology, which is evident from the keywords "Artificial Intelligence", "Blockchain", "Edge computing", and "Data Analytics", and "Agricultural robots", which are beginning to be applied most in that period.

The focus on the application of these technologies, i.e. the results of research in 2021, became the basis for research that appears in early 2022, marked by keywords such as deep learning, "neural networks", "machine-learning" and "forecasting". In other words, researchers are focusing on keywords that are primarily related to the use and utilization of artificial intelligence, or machine learning.

4. Discussion

The growing importance of research on the development of smart cities grows with the increase in urban population since the growth of urban population brings with it the challenge of ensuring a satisfactory quality of life for all residents, and rational use of resources. It is estimated that by 2040 almost 67% of the world's population will live in urban areas (Moustafa et al., 2018), which means challenges related to ensuring enough energy for the normal functioning of urban areas (Eicker, 2019), sufficient drinking water (Sanchez et al., 2020), access to services these include health care, education, security and other.

The increase in the urban population leads to the emergence of challenges related to traffic congestion, i.e. air pollution, which is associated with an increase in the number of vehicles on roads in urban areas (Rajé et al., 2018). Given this, there is a need associated with differential regulation of traffic flows, i.e. emphasizing the use of sustainable means of transport, which in urban areas means the use of public transport, electric vehicles or ultimately vehicles such as bicycles.

All the described challenges affect the risk of the unsustainability of the urban area, i.e. the emergence of risks associated with the irrational use of resources, which will result in the depletion of available resources for future generations. One of the possible solutions to the described challenges in the development of smart cities, i.e. the trans-formation of traditional cities into smart cities using technologies and technological innovations provided by Industry 4.0.

One of the most important technologies of Industry 4.0 that can be used in the management of urban areas is smart sensors or the Internet of Things. Internet of Things technology can be applied for more efficient waste management, automation of space or buildings, management of transport systems and the like (Liu, 2018). In addition to the

Internet of Things, the application of digital twin's technology enables virtualization of urban areas and based on the implemented virtualization simulation of potential improvements or simulation of processes in urban areas, which is especially useful when talking about resilience development if a crisis occurs. On the other hand, the application of digital twins enables simpler and more efficient planning, which affects the management of the city itself (Jiang et al., 2022). Furthermore, if smart sensors are interconnected and databases are created, the collection of large amounts of data allows the creation of big data whose analysis can identify trends related to processes taking place in urban areas, i.e. the data obtained can be used to decide on improvement (Pan et al., 2016).

When it comes to increasing energy efficiency, i.e. reducing energy consumption in urban areas, Industry 4.0 technology that is particularly important is the Internet of Things, which can be used to monitor current energy consumption in urban areas or predict future consumption, which can be the basis for making decisions that will increase energy efficiency, i.e. reduce energy consumption (Zhang et al., 2021). In addition, the application of artificial intelligence can also increase energy efficiency, primarily through the development of artificial intelligence that will monitor or analyze trends related to climate change, water management and water supply and similar (Saheb et al., 2022). In addition, the application of artificial intelligence is particularly important if it is linked to big data where big data is used as a database based on the analysis to be made, for which artificial intelligence can be used. The importance of using artificial intelligence in this context is especially important due to the complexity and a large amount of data that make up big data, which means the complexity of its analysis for humans, i.e. the long time required to conduct analysis (Allam and Dhunny, 2019).

If the described technologies are placed in the context of research results, the focus of researchers shows that an increasing number of them are beginning to deal with the application of artificial intelligence in urban areas, and how artificial intelligence can be used in the context of smart cities. The reason for this can be found in the complexity of urban areas and the potential lack of capacity of people when analyzing large amounts of data and making quick and effective solutions to problems identified in urban areas.

Also, a particularly important area when talking about urban areas is the use of clean energy, i.e. reducing the need for energy, which is one of the fundamental goals of smart cities. The need to increase energy efficiency grows with the increase in the number of inhabitants in cities, i.e. the reduction of available resources that can be used for energy production.

Undoubtedly, there is a significant impact of Industry 4.0 technologies on the development of smart cities, and in general on the functioning of urban areas. Application of Industry 4.0 technologies in addition to its advantages, brings with it risks that are primarily related to cybersecurity, since it is necessary for the normal functioning of Industry 4.0 technologies to ensure digital connectivity between technologies. Cybersecurity is especially important when it comes to smart cities, given that smart cities are based on the application of Industry 4.0 technologies or digitalization of the process.

5. Conclusion

In this research, a systematic analysis of the impact of Industry 4.0 on the development of smart cities was conducted. The research included 373 papers that were indexed in the SCOPUS database. The research identified Zheng Liu from Canada, Theodore E. Matikas from Greece, Anastasios C. Mpalaskas from Greece and Miroslav Svítek

from the Czech Republic as the most productive authors writing and researching the impact of Industry 4.0 on the development of smart cities. All the mentioned authors have 4 articles in the field of the impact of Industry 4.0 on smart cities. Furthermore, the study identified the country with the highest number of papers and it is China with a total of 68 published papers, while the institutions with the highest number of published papers were the University of Aveiro in Portugal, the University of Johannesburg in South Africa and the University of São Paulo in Brazil. All the mentioned institutions have 7 published works each. When discussing papers that have the highest number of citations, it was identified that the paper "Fog of everything: Energy-efficient networked computing architects, research challenges, and a case study" by Baccarelli, Naranjo, Scarpiniti, Shojafar and Abawajy has the highest number of citations, that is, 224 of them.

Looking at keywords and the development of keywords in the observed period from 2016 to 2021, it is identified how there is a change in the trend in perceiving technologies and the impact of technology on smart cities, and how the trend relates to changing data research according to the trend of research that looks at the possibilities of applying artificial intelligence in smart cities, or the application of machine learning as one of the methods of learning artificial intelligence systems.

The research identified the growing importance of smart cities due to the increase in the number of inhabitants living in urban areas, and how researchers are looking at smart cities as solutions to challenges that arise with the increasing urban population. Furthermore, the research identified that smart cities are the answer to the transformation of traditional cities into green, i.e. sustainable cities and that the development of smart cities is one of the fundamental goals of sustainable development. However, the development of smart cities as well as smart cities as such is a new area and it has been identified that an insufficient number of authors are dealing with the application, related to keyword trends, artificial intelligence and the potential of artificial intelligence to manage smart cities. Given this, the recommendations for future researchers in this field relate to research that would link artificial intelligence with smart cities and the possibility of managing certain subsystems within the smart city through artificial intelligence.

Based on the conducted research, the answers to the research questions were identified. It has been identified that Industry 4.0 has an impact on smart cities and the development of smart cities through technologies and technological innovations being developed within Industry 4.0 so that Industry 4.0 technologies can be used as a mechanism for transforming traditional cities into smart cities, i.e. achieving the goals of smart cities themselves.

On the other hand, it was identified that the answer to the second research question is which of the technologies of Industry 4.0 have the most significant impact on the development of smart cities, the Internet of things, or artificial intelligence. The application of Internet of things technology enables the connection of several systems into one whole, i.e. it enables the communication between several subsystems of smart cities, which can facilitate the management, i.e. make the management of smart cities more efficient.

This research has limitations. The primary restriction refers to the review of only papers published in the SCOPUS database and the review of only scientific papers published in journals or conference proceedings without considering the books and other papers related to the observed area. It is recommended that future researchers conduct an analysis that would include papers from the WOS database, i.e. analyze books and other papers that talk about the impact of Industry 4.0 on smart cities.

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