Big Data, the Internet of Things and Smart Cities Research: A Literature Review and Research Agenda

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Abstract. This study aims at providing a literature review of big data, the Internet of Things and Smart cities research using SCOPUS, which is considered as the largest abstract and citation database of peer-reviewed literature. The research identified 143 relevant papers. The analyses of distribution of papers by year of publication, subject area, country, type, top 10 authors, and source are presented and discussed. A research agenda for future research is provided.

Keywords: Big Data, Internet of Things, Smart cities, literature review.

1 Introduction

Cities have always been at the heart of innovation. This is even more crucial in the twenty-first century with the United Nations predictions of a rapid growth in the urban population that may reach about 2.5 billion new people by 2050 [1]. This accelerating growth may become unsustainable if the cities relies on the traditional systems to deliver both economic and social resources [2]. Recently, the emergence of cutting edge tools and technological innovations, including the Internet of Things (IoT), big data analytics (BDA), predictive analytics, and industry 4.0 has created a renewal of interests toward studying cities [3-5]. Indeed, the adoption and use of these new tools and technologies are creating the so-called Smart cities, which can be defined as the use of "networked infrastructures to improve economic and political efficiency and enable socio, cultural and urban development" (p. 307) [6]. For example, [7] argued that the use of the "Internet of Things and big data analytics, can develop the smart city and smart industry" [7], and thus, help to ease the current pain points associated to traffic congestion, waste and pollution management and energy

efficiency that may bring the city liveability to new levels that haven't been seen before [2].

Similarly, Hashem et al. [8] argued that the growth of BDA and the development of Io T related technologies are paving the way in the feasibility and realization of smart city initiatives. They argued that BDA "offer the potential for cities to obtain valuable insights from a large amount of data collected through various sources, and the IoT allows the integration of sensors, radio-frequency identification, and Bluetooth in the real-world environment using highly networked services" [8]. Various scholars have also acknowledged the contribution of these technological innovations in solving various issues faced by today's cities including: job creation, economic growth, environmental sustainability, and social resilience [9].

Cities related tools and concepts have the capability of enhancing the quality of life of urban citizens by substantially improving the quality of development and delivery of various services including transportation, healthcare, electricity and water supply, education, and public security [9, 10].

[11] claimed that IT-enabled smart cities will bring positive social change, and thus enrich "governance and human capital among the citizenry" (p. 43)[11].

[12] argued that "while the technical issues needed to create the Internet of Things are substantial, little attention has been given to the behavioral, organizational and business issues that are necessary for a better understanding of the adoption, usage and impact of the IoT" (p. 1).

Despite the high potential related to the joint impact of BDA and IoT related tools in improving today's cities, we know little about the level of current studies on these topics. In fact, [8] claimed that the combination of the BDA and IoT is "an unexplored research area that has brought new and interesting challenges for achieving the goal of future smart cities" [8]. Therefore, this study is an initial attempt to fill the knowledge gap identified in the literature. More specifically, this study aims at examining the following research questions:

1. What is the current level of research on BDA and IoT related topics in the smart cities context?
2. Where should future efforts be directed to accelerate the adoption and use of BDA and IoT related topics in smart cities?

To address our research questions, we will draw on the literature on BDA and IoT related topics in smart cities and a literature review conducted on these topics within the database called SCOPUS.

The rest of this paper is structured as follows: Section 2 is concerned with the description of our research methodology; Section 3 presents and discusses the results; Section 4 provides the conclusion as well as future research directions.

2 Methodology

In this study, we follow an approach derived from prior studies [13, 14] that uses the following steps: (1) conduct a search using a combination of the following keywords: "smart cities" or "smart city" or "intelligent city" or "intelligent cities" and "big data" or "predictive analytics" and "internet of thing*" or "web of thing*" or

"web of people" or "industry 3.0" or "industry 4.0" or "internet of object*" within the SCOPUS database. SCOPUS is considered as the largest abstract and citation database of peer-reviewed literature: scientific journals, books and conference proceedings. The database delivers a comprehensive overview of the world's research output in the fields of science, technology, medicine, social sciences, arts and humanities. It provides a set of tools to track, analyze and visualize research [15].

Our search was realized on June 22, 2017. The search resulted in 145 papers dealing with the topic. A quick analysis allowed us to remove two duplicated papers [16, 17], and thus resulting in a final set of 143 papers.

3   Results and discussion

In this section, we are going to present and discuss the key findings of the big data, predictive analytics and IoT-related topics for smart cities articles identified by our search within SCOPUS[5, 7-9, 16-154].

In Table 1, we have the distribution of publications by year . There is a constant increase of papers published on the topic since 2014. We went from 16 papers (11%) published in 2014 to 30 papers in 2015 (21%), and 62 papers in 2016 (43%). In June 22, 2017, we already had 33 articles (23%) which is more than all papers published in 2015 or 2014.

Table 1. Distribution of publications by year

Year	# of papers	%
2017	33	23%
2016	62	43%
2015	30	21%
2014	16	11%
2013	2	1%
Total	**143**	**100%**

Table 2. Distribution of publications by subject area

Subject area	#of papers	%
Computer Science	120	52%
Engineering	35	15%
Mathematics	20	9%
Social Sciences	13	6%
Decision Sciences	10	4%
Energy	8	3%
Business, Management and Accounting	4	2%
Earth and Planetary Sciences	4	2%
Environmental Science	4	2%
Materials Science	3	1%
Medicine	3	1%

Physics and Astronomy	3	1%
Pharmacology, Toxicology and pharmaceutics	2	1%
Arts and Humanities	1	0%
Biochemistry, Genetics and Molecular Biology	1	0%
Chemistry	1	0%
Health Professions	1	0%
Total*	**233**	**100%**

*Some articles are counted more than once because they cover more than one subject area.

Table 2 presents the distribution of articles by subject area. This table is dominated by 'Computer Science' subjects with 120 papers (52%), followed by 'Engineering' with 35 papers (15%), 'Mathematics' with 20 papers (9%), 'Social Sciences' with 13 papers (6%), and 'Decision Sciences' with 10 papers (4%).

The distribution of articles by country is presented in Table 3. It is undoubtedly clear that China and the United States are leading the research on the topic with respectively 22 papers (11%) and 20 papers (10%), followed by Italy and Spain with 14 papers each (7%), then Switzerland with 11 papers (6%).

Table 3. Distribution of publications by country

Country	# of papers	%
China	22	11%
United States	20	10%
Italy	14	7%
Spain	14	7%
Switzerland	11	6%
Germany	9	5%
India	8	4%
South Korea	8	4%
United Kingdom	8	4%
Australia	7	4%
Austria	5	3%
France	5	3%
Russian Federation	5	3%
Canada	3	2%
Colombia	3	2%
Denmark	3	2%
Japan	3	2%
Macedonia	3	2%
Netherlands	3	2%
Portugal	3	2%

Country	# of papers	%
Saudi Arabia	3	2%
Sweden	3	2%
Finland	2	1%
Greece	2	1%
Iran	1	1%
Nigeria	2	1%
Singapore	2	1%
Taiwan	2	1%
United Arab Emirates	2	1%
Belgium	1	1%
Brazil	1	1%
Brunei Darussalam	1	1%
Ecuador	1	1%
Egypt	1	1%
Latvia	1	1%
Malaysia	1	1%
Mexico	1	1%
Morocco	1	1%
Norway	1	1%
Poland	1	1%
Romania	1	1%
Serbia	1	1%
Slovakia	1	1%
South Africa	1	1%
Undefined	1	1%
Total*	**192**	**100%**

*Some articles are counted more than one time as their authors come from more than one country.

From Table 4, we can see that the distribution of papers by type of document is dominated by 'Conference Paper' with 83 documents (58%), followed by 'Article' with 40 documents (28%), 6 'Review' (4.2%), 'Conference Review' with 5 documents (3.5%), 'Book Chapter' with 3 documents (2.1%), 'Article in Press' with 4 documents (2.8%), and Editorial and Note with each 1 document (0.7%).

Table 4. Distribution of documents by type

Documents type	Number	%
Conference Paper	83	58,0%
Article	40	28,0%
Review	6	4,2%
Conference Review	5	3,5%
Book Chapter	3	2,1%
Article in Press	4	2,8%
Editorial	1	0,7%
Note	1	0,7%
Total	**143**	**100%**

Overall, we found 159 scholars working on the topic. Table 5 provides the List of top 10 authors. Jara, A.J. dominates this list with 7 papers, closely followed by Ahmad, A. and Paul, A. with 6 papers each. Then, we have Bocchi, Y., Genoud, D., Rathore, M.M., Dustdar, S., Galache, J.A.,Inzinger, C., and Schleicher, J.M. with 5 papers each.

Table 5. List of top 10 authors

Author	# of papers
Jara, A.J.	7
Ahmad, A.	6
Paul, A.	6
Bocchi, Y.	5
Genoud, D.	5
Rathore, M.M.	5
Dustdar, S.	5
Galache, J.A.	5
Inzinger, C.	5
Schleicher, J.M.	5

Overall, we found 54 sources of papers. The top 10 are presented in Table 6. The largest number of documents is from the 'Lecture Notes In Computer Science Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics' with 11 papers.

4 Conclusion and future research directions

The main objective of this study was to provide a literature review of BDA, the IoT and Smart cities research using SCOPUS. Our search identified 143 relevant papers. The distribution of papers found by year of publication, subject area, country, type, top 10 authors, and sources have been presented and discussed.

The literature review showed that while there is a constant increase of papers published on the topic since 2014 (e.g., from 16 papers (11%) published in 2014 to 30 papers in 2015 (21%), and 62 papers in 2016 (43%) and 33 articles (23%) by June 22, 2017), the clear majority of papers are still 'Conference Paper' (58%). Therefore, more research needs to be published by journals, especially top operations management and information systems journals. Indeed, no papers were identified from these outlets which are recognized to publish cutting edge studies. More importantly, studies should focus on the best strategy to select, adopt, implement and foster the use of the IoT, BDA, predictive analytics, and industry 4.0 in the context of smart cities.

The literature review also showed that very few studies were conducted on cities from underdeveloped countries, which face huge challenges including waste management, electricity and water supply, traffic congestion, urban planning, security and public services design and delivery. Assessing how the IoT, BDA, predictive analytics, and industry 4.0 related tools and technologies can contribute to solve these issues should be included into future research.

[10] argued that "continuous growth of the complex urban networks is significantly challenged by real-time data processing and intelligent decision-making capabilities", therefore, exploring the contribution of the IoT, BDA, predictive analytics, and industry 4.0 related tools and technologies in solving this challenge is an interesting research avenue.

Exploring how the IoT, BDA, predictive analytics, and industry 4.0 related tools and technologies impact citizens' privacy should also be included into future research agenda.

Assessing the cost of the adoption of these tools by various cities across the world should be included in future research directions. What are the best practices? How can they be shared? How these costs are going to influence the council tax system?

It would be interesting to expand our findings to other key databases such as ABI/Inform Complete, Academic Search Complete, Business Source Complete, Emerald, IEEE Xplore, Science Direct, and Taylor & Francis as well as in the Association of Information Systems (AIS) basket of top journals.

Table 6. Distribution of articles by sources

	Source	# of papers
1.	Lecture Notes In Computer Science Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics	11
2.	ACM International Conference Proceeding Series	4
3.	IEEE Internet Computing	3
4.	IEEE Pervasive Computing	3
5.	Studies In Computational Intelligence	3
6.	IEEE Access	2
7.	International Journal Of Pharmacy And Technology	2
8.	International Journal On Semantic Web And Information Systems	2
9.	Lecture Notes In Electrical Engineering	2
10.	Software Practice And Experience	2

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