ConBRepro
X CONGRESSO BRASILEIRO DE ENGENHARIA DE PRODUÇÃO
EVENTO ON-LINE
02 a 04 de dezembro 2020

APPLICABLE CROWDSENSING TECHNIQUES FOR SMART CITIES: A BIBLIOMETRIC REVIEW

Tibério Bruno Rocha e Cruz
PPGEP - UTFPR
Tatiana C. de Severo Pasquini
PPGEP – UTFPR
Ph.d Regina Negri Pagani
PPGEP - UTFPR
Ph.d Eliane Fernandes Pietrovski
PPGEP - UTFPR

Abstract: The United Nations project that 68% of the world population will be living in urban areas by the year 2050. Due to the growing importance of urban living, making cities a better place to live has become a more relevant theme. However, not all countries have the economical conditions to implement costly hardware, therefore, crowdsensing becomes a feasible alternative. The aim of this study is to perform a bibliometric review of crowdsensing techniques that could be applicable to Smart Cities.

Keywords: Crowdsensing; Smart Cities; Technology.

1. Introduction

According to the United Nations (UN), by the year 2050 68% of the world population is projected to live in urban areas. Therefore, there is a growing concern on how to make cities a better place to live. Elements concerning technology, people and community such as: infrastructure, mobility, economy and the environment are some of the issues that need improvement (NAM; PARDO, 2011).

As the population grows resources become scarce, thus, a smarter way to manage them becomes paramount. In this sense, to promote the necessary improvements that a city needs, with the help of technology, the concept of a Smart City arises. A city that is smarter can be understood as a city more readily able to deal with everyday problems (ALBINO *et al*., 2015).

Although there are many definitions as to what constitutes a Smart City, it is possible to name three recurrent components: instrumentation, interconnectivity and intelligence (HARRISON *et al*., 2010). Out of those three components, instrumentation may present a challenge to cities where there is no technological structure or financial resources to equip the city. Sensors and devices of other types, such as cameras and measurement equipment,

among others can be costly. However, there is an interesting alternative that can be considered: crowdsourcing. The term crowdsourcing is the union of two words, crowd and outsourcing, that is, to use a crowd to outsource a given task (BARROSO et al., 2016).

Among the tasks needed in a smart city, the one of collecting data is an important one. Instead of using costly sensors and devices, it is possible to use citizens as sensors, and for this, the technique of crowdsensing can be helpful. Crowdsensing is using citizens as sensors to collect data that can be useful in solving urban issues such as: transportation, health, infrastructure, security, environment, among others (R. K. GANTI, 2011).

Using citizens as sensors instead of investing in hardware might prove to be more economically feasible, thus, through citizen participation and engagement, effectively helping to make cities a better place to live.Therefore, this study aims to perform a bibliometric review of crowdsensing techniques that could be applicable to Smart Cities.

This paper is divided into 6 sections, being this first one the Introduction. Section 2 describes the methodology used, number 3 presents the theoretical background, section 4 shows the results, section 5 the conclusion and finally in section number 6 the acknowledgments.

2. Methodology

In order to have a relevant survey the research was conducted with a systematic approach by applying the Methodi Ordinatio methodology (PAGANI et al., 2015; 2018). It consists of a systematic review where articles are ranked according to established metrics seeking to build a portfolio of the most relevant studies to the present research.

Firstly, the keywords were defined, namely: Crowdsensing; Smart Cities; Technology. In order to find these three concepts, the Boolean operator AND was used, and the final research sintaxe was defined as: "Crowdsensing" AND "Smart Cities" AND "Technology". Three databases were used for this study: Scopus, Science Direct and Web of Science and the following results were found as seen in Table 1.

Table 1 – Databases and results

Keywords	**Database Results**				
	Scopus	**Science Direct**	**Web of Knowledge**	**Gross**	**Final number of papers**
"Crowdsensing" AND "Smart Cities" AND "Technology"	19 document results TITLE-ABS-KEY (*"Crowdsensing"* AND *"Smart Cities"* AND *"technology"*) AND DOCTYPE (*ar*)	Search results: 4 (*"Crowdsensing"* AND *"Smart Cities"* AND *"technology"*)	Resultados: 6 Você pesquisou por: TÓPICO: ("Crowdsensing" AND "Smart Cities" AND "technology")Refinado por: TIPOS DE DOCUMENTO: (ARTICLE)	29	20

Source: Author (2020)

It is important to mention that no time limit was used and the type of documents searched were articles only. The research option that was selected on Scopus and ScienceDirect were Article title, Abstract and Keywords; on Web of Knowledge the chosen option was topic. The total number of papers found was 29. After eliminating duplicates the final number of papers was 20, which shows the novelty and relevance of the approached theme.

3. Theoretical background

As time progresses, the limits of knowledge expand, and with that, the understanding of some concepts changes and improves. This section exposes the theoretical background and concepts that are presented in this study. It begins with the definition of smart cities, afterwards the concept of crowdsourcing is presented, and finally, the crowdsensing technique which is embedded in crowdsourcing.

3.1. Smart Cities

The concept of smart cities has been the subject of study, and has been defined in different ways. The term was first used in the 1990s. The emergence of the term, emphasis was placed on technological solutions to problems of infrastructure within cities (ALBINO et al., 2015).

A Smart city can be understood as the incorporation of information in its infrastructure (NAM; PARDO, 2011), as well as the application of ICT (Information and communications technology) on human capital, education, social and environmental (LOMBARDI et al., 2012), or also as a connection of physical, technological infrastructures, social and business elements to leverage the intelligence of cities.

Thus, Harrison et al. (2010) based its concept of smart cities on the definition brought by the International Business Machines Corporation (IBM) on what would be a more intelligent planet. The authors et al. states that an integrated structure allows cities to unite, integrate, analyze, optimize and make decisions based on operational data. This integrated structure is constituted by technological aspects such as: instrumentation, interconnectivity and intelligence, which are defined in Table 2:

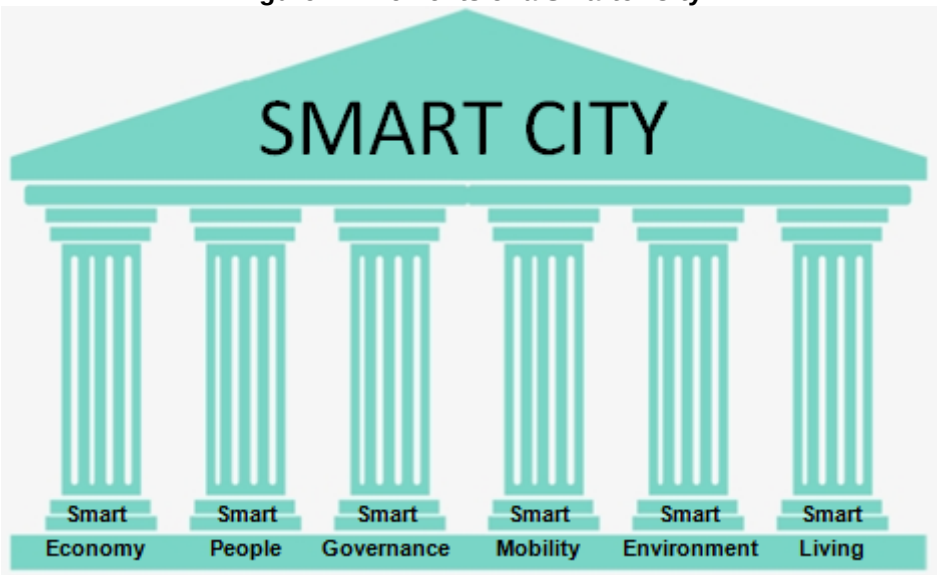
Table 2 - Elements of Smart Cities and their definitions

Elements	Definition
Instrumentation	It constitutes the source of data, in real time, that represents the operation of the physical infrastructure and services. They are measuring instruments that serve to connect the real world to the virtual world.
Interconnectivity	The integration of data and information obtained through instrumentation.
Intelligence	The analysis of data and interconnected information obtained through the instrumentation must aid the process of inference and decision making

Source: Adapted from Nam and Pardo (2011).

Technology is very important for smart cities, but the improvement of technological aspects should serve the quality of life of the city's population (LOMBARDI et al., 2012). Therefore, in order to make citizens' lives better, a smarter city must effectively and efficiently, and perhaps most importantly, intelligently, manage: economy, people, government, mobility, environment and living. As seen in Figure 1:

Figure 1 - Elements of a Smarter City



Source: Adapted from Batty, M. et al., (2012)

In this way, technology in smart cities can only be seen as smart if it promotes solutions that are at the service of people's quality of life (NAM;PARDO, 2011). One way to promote smart solutions seeking citizen participation is through crowdsourcing, a model where a crowd outsources a given task

3.2. Crowdsourcing

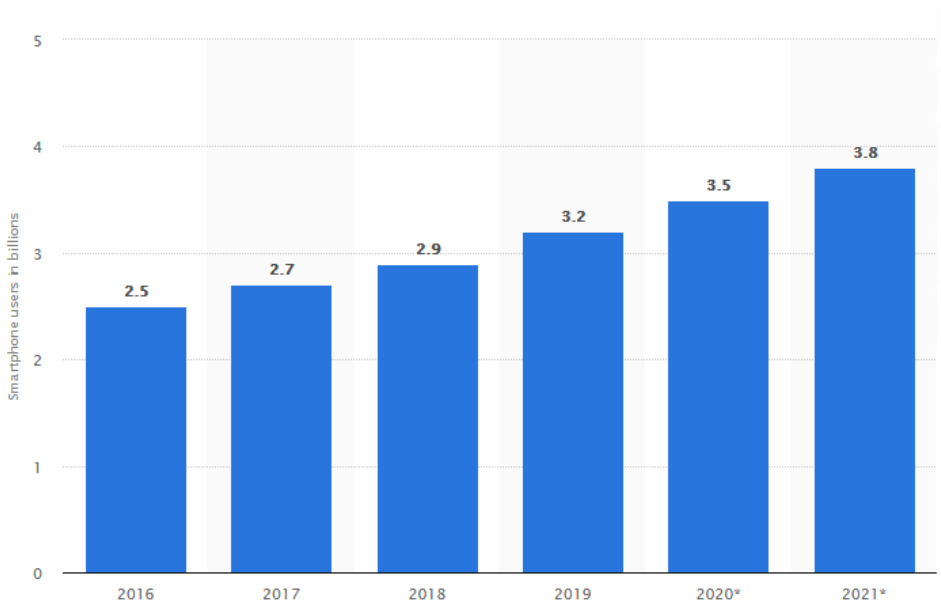
The term was first coined by Howe in 2006 and defined as: "the act of a company or institution outsourcing a task, previously performed by employees, to an indefinite (and usually large) network of people in the form of an open call". The term crowdsourcing is the union of two words, crowd and outsourcing, that is, the use of a crowd to outsource data and information collection (BARROSO et al., 2016).

The knowledge and unexplored participation of citizens is a valuable asset. To fill this gap, the concept of crowdsourcing arises, which consists of online platforms to collect ideas, responses and solutions from the crowd (LEE et al., 2017).Typically the information and data needed for decision making in cities is provided by the government and other organizations. In this way, citizens' knowledge is an untapped asset in smart cities, a place where there is the opportunity to collect data and information via crowdsourcing and can occur efficiently and effectively (LEE et al., 2016).

3.3. Crowdsensing

According to (statista.com), as seen in Figure 2, 3.8 billion people in the world will have smartphones by the year 2021. They have embedded powerful sensors such as: accelerometer, digital compass, gyroscope, GPS, microphone, thermometer, air humidity sensor, camera and even a Geiger counter to measure radiation levels.

Figure 2 – Number of smartphone users



Source: www.statista.com (2020)

These sensors can collectively monitor a wide set human activities as well as the environment (DEJUN YANG et al., 2016). Collecting data in a large city can pose a big challenge to Smart Cities. While crowdsourcing is task based, crowdsensing is information based, that is, the first aims to solve complex problems by dividing them into smaller tasks, the latter, seeks to split the responsibility of harvesting information (CARDONE GIUSEPPPE et al., 2013).

Therefore, due to the widespread use of mobile devices, crowdsensing brings great opportunities for data collections while interacting with the physical world. People can also monitor their working environments and share the emerging and appropriate information with their colleagues, in order to report unsafe conditions and make it known to their peers that could be potentially affected readily (XIPING HU et al., 2013). Infrastructure information can also be gathered, for example, measuring traffic congestion, road conditions, parking availability, outages of public works (e.g., malfunctioning fire hydrants, broken traffic lights), and real-time transit tracking. (RAGHU K. GANTI et al., 2011).

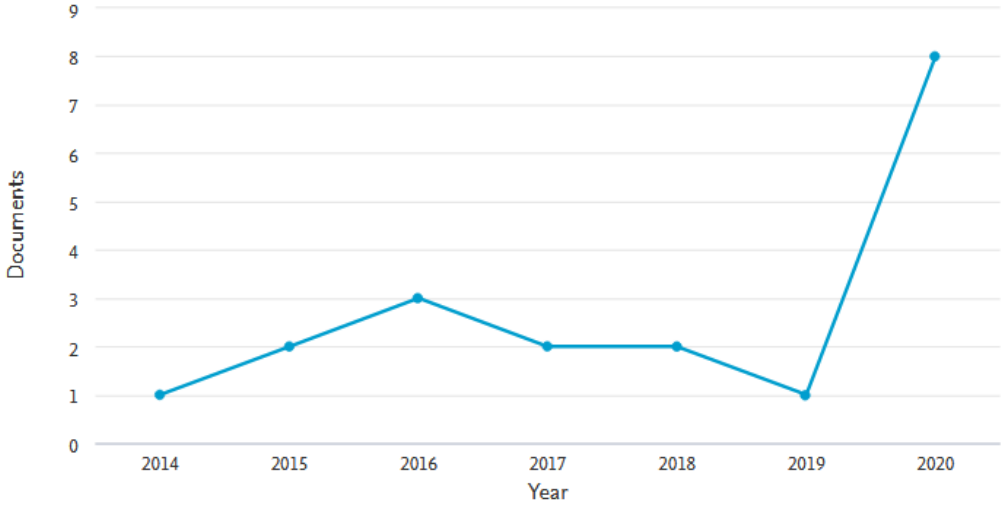
There is an untapped potential behind the powerful sensors of mobile and smartphone devices. The amount of information that can be gathered collectively would be of great use in making cities smarter.

4. Results and discussion

This section presents the bibliometric analysis of the results obtained in this research. The parameters chosen for the analysis and discussion are: year of publication, author, country or territory and subject area. Out of the three databases that the research was conducted only Science Direct does not have the analysis feature, however, the other two databases comprise the majority of the results. All the results obtained on Scopus were also obtained on Web of Science; therefore, the charts presented in this section were the ones generated on Scopus, being that, all these comprise also the results obtained on Web of Science. The results found on ScienceDirect are commented at the end of this section.

The first parameter presented is the year of publication. Even though there was no time limit set for the research, the time window of results is narrow, the first year being is 2014 and the latter 2020; therefore, Figure 3 shows that the topic of crowdsensing technologies that can be applied in smart cities is recent.

Figure 3 – Documents by year

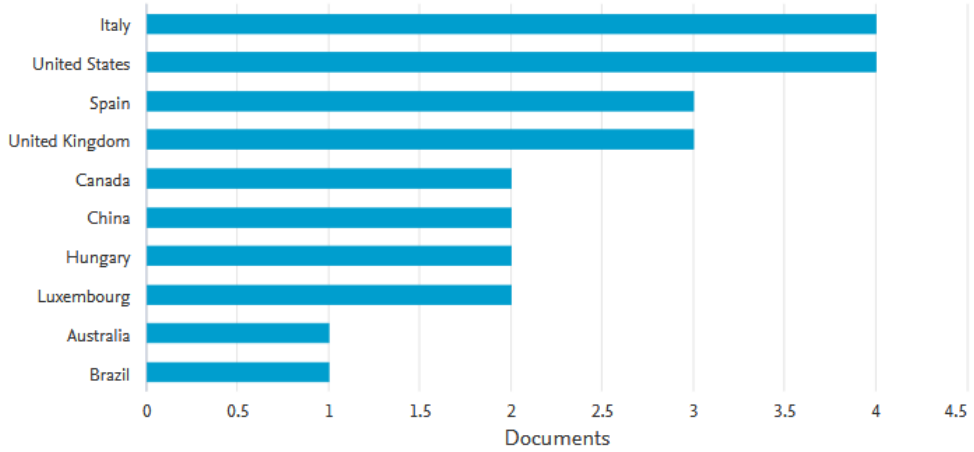


Source – Scopus (2020)

Also, it is noted that in the year 2020 there was an increase in the number of publications, if compared to the total, relatively, the number is quite relevant.

The analysis obtained through territory or country shows that the countries with the highest number of publications are Italy and the United States with four publications each. The results are shown in Figure 4.

Figure 4 – Documents by country or territory

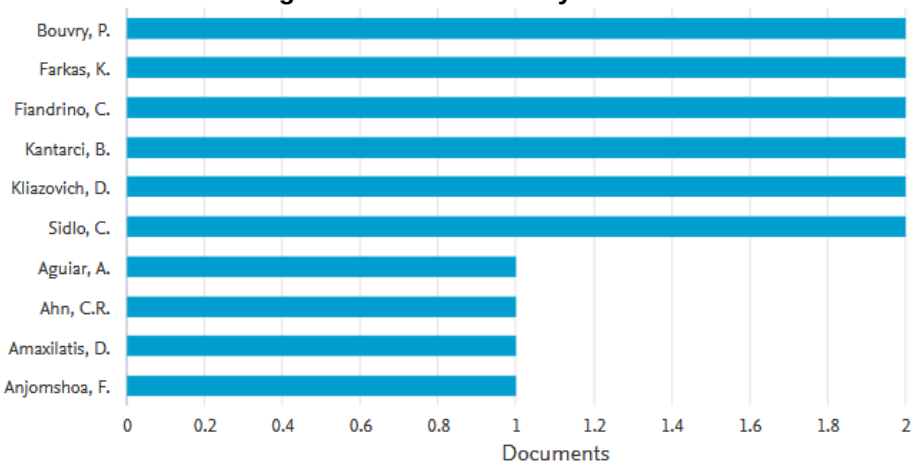


Source – Scopus (2020)

Spain and the UK follow with three publications each and lastly there is Canada, Hungary and Luxemburg. These close results show that there are no leading countries in production of studies.

The next parameter that was analyzed is publications by the author. The results are shown in Figure 5.

Figure 5 – Documents by author

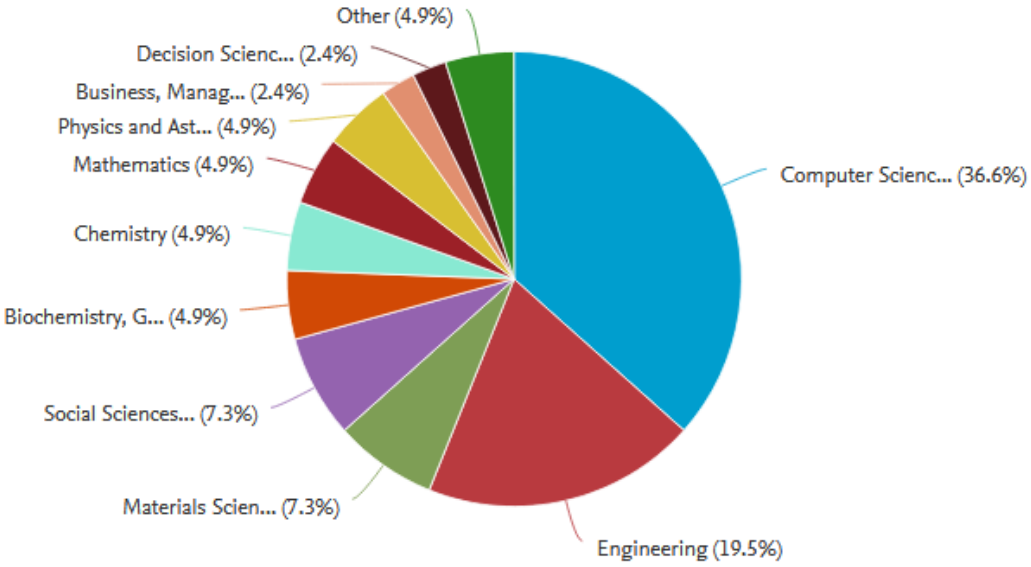


Source – Scopus (2020)

There are six authors with two publications each, followed by four authors with one publication each. This also shows that there are no leading authors in the studied theme.

The last parameter that is going to be discussed is documents by subject area. The articles resulting from the research are distributed among ten subject areas, namely: Computer Science, Engineering, Materials Science, Biochemistry, Genetics and Molecular Biology, Chemistry, Mathematics, Physics and Astronomy, Social Sciences, Earth and Planetary Sciences and Energy. Figure 6 presents the subject areas in a pie chart.

Figure 6 – Documents by subject area



Source – Scopus (2020)

It is noted in Figure 5 that the subject area with the highest number of articles is Computer Science, followed by Engineering. The number of publications by area is shown in Table 2.

Table 2 – Number of publications by subject area

Subject area	Nº
Computer Science	14

Engineering	8
Materials Science	3
Biochemistry, Genetics and Molecular Biology	2
Chemistry	2
Mathematics	2
Physics and Astronomy	2
Social Sciences	2
Earth and Planetary Sciences	1
Energy	1

Source – Scopus (2020)

Computer Science is at the top of the list with 14 publications, followed by Engineering with 8. The other subject areas have a quite even number of publications.

Finally, three articles were found on Science Direct, however, the database does not provide a deeper analysis feature on its website; therefore, this study was not able to include its results on the analysis performed.

5. Conclusion

The objective of this study was to carry out a bibliometric review of practical technological applications of crowdsensing in Smart Cities, the parameters chosen for the analysis were: year of publication; territory or country; authors and area of study. The analysis sought to understand the context in which crowdsensing applied to Smart Cities is found. The systematic review of the literature presented 20 relevant articles. The most relevant and most notable result of the analysis was the recent relevance of the topic in the year 2020. It was also noted that there is a predominance in the area of knowledge led by computer science. In the articles found, frameworks, applications, tools and platforms were proposed to solve urban issues in the areas of public transport, communication, car circulation, the environment and others. They also provide solutions to monitor air quality, environmental noise, bridge vibration and the reckless behavior of drivers.

This study contributes by showing that there is a growth in crowdsensing applications to Smart Cities. For future works, it is interesting to identify opportunities for crowdsensing applications in Smart Cities and to find out if they are at the service of quality of life and sustainable development.

6. Acknowledgments

It is necessary to thank the UTFPR and the post graduation program PPGEP for the support and the effort in incentivizing academic research, as well as, a special thanks to Ph.D Regina Negri Pagani for coordinating this study.

References

AMAXILATIS, D., MYLONAS, G., DIEZ, L., THEODORIDIS, E., GUTIÉRREZ, V., MUÑOZ, L. Managing pervasive sensing campaigns via an experimentation-as-a-service platform for smart cities, **Sensors (Switzerland)**, 2018.

BATTY, M., AXHAUSEN, K.W., GIANNOTTI, F., POZDNOUKHOV, A., BAZZANI, A., WACHOWICZ, M., OUZOUNIS, G. PORTUGALI, Y. Smart cities of the future, **European Physical Journal: Special Topics**, 2012.

BELLI, D., CHESSA, S., FOSCHINI, L., GIROLAMI, M. A Probabilistic Model for the Deployment of Human-Enabled Edge Computing in Massive Sensing Scenarios, **IEEE Internet of Things Journal**, 2020.

DE FILIPPI, F., COSCIA, C., BOELLA, G., ANTONINI, A., CALAFIORE, A., CANTINI, A., GUIDO, R., SCHIFANELLA, C. MiraMap: A We-Government Tool for Smart Peripheries in Smart Cities, **IEEE Access**, 2016.

FARKAS, K., FEHÉR, G., BENCZÚR, A., SIDLO, C.Crowdsensing based public transport information service in smart cities. **Infocommunications,** 2014.

FIANDRINO, C., ANJOMSHOA, F., KANTARCI, B., KLIAZOVICH, D., BOUVRY, P., MATTHEWS, J.N. Sociability-Driven Framework for Data Acquisition in Mobile Crowdsensing over Fog Computing Platforms for Smart Cities, **IEEE Transactions,** 2017.

FIANDRINO, C., CAPPONI, A., CACCIATORE, G., KLIAZOVICH, D., SORGER, U., BOUVRY, P., KANTARCI, B., GIORDANO, S. CrowdSenSim: A simulation platform for mobile crowdsensing in realistic urban environments, **IEEE Access**, 2017.

HARRISON, C et al. Foundations for Smarter Cities. **IBM Journal of Research and Development**, 2010.

HÎRŢAN, L.-A., DOBRE, C., GONZÁLEZ-VÉLEZ, H. Blockchain-based reputation for intelligent transportation systems, **Sensors (Switzerland)**, 2020.

HU, J., YANG, K., WANG, K., ZHANG, K. A Blockchain-Based Reward Mechanism for Mobile Crowdsensing, **IEEE Transactions on Computational Social Systems**, 2020.

KIM, M,. KIM Y. Multi-blockchain structure for a crowdsensing-based smart parking system, **Future Internet** 2020.

LONGO, A., ZAPPATORE, M., DE MATTEIS, A. An osmotic computing infrastructure for urban pollution monitoring, **Software - Practice and Experience**, 2020.

NAM, T.; PARDO, T.A. Conceptualizing Smart City with Dimensions of Technology, People, and Institutions. **Proc. 12th Conference on Digital Government Research, College Park, MD**, 2011.

R. K. GANTI, F. YE AND H. LEI. Mobile crowdsensing: current state and future challenges. **IEEE Communications Magazine**, 2011.

REGALIA, B., MCKENZIE, G., GAO, S., JANOWICZ, K. Crowdsensing smart ambient environments and services,**Transactions in GIS**, 2016.

SALIM, F., HAQUE, U. Urban computing in the wild: A survey on large scale participation and citizen engagement with ubiquitous computing, cyber physical systems, and Internet of Things, **International Journal of Human Computer**, 2015.

SANTOS, P.M., RODRIGUES, J.G.P., CRUZ, S.B., LOURENÇO, T., D'OREY, P.M., LUIS, Y., ROCHA, C., BARROS, J. PortoLivingLab: An IoT-Based Sensing Platform for Smart Cities, **IEEE Internet of Things Journal**, 2018.

SILVA, M., SIGNORETTI, G., OLIVEIRA, J., SILVA, I., COSTA, D.G. A crowdsensing platform for monitoring of vehicular emissions: A smart city perspective, **Future Internet**, 2019.

SUN, Y., SONG, H., JARA, A.J., BIE, R. Internet of Things and Big Data Analytics for Smart and Connected Communities, **IEEE Access**, 2016.

UN – United Nations. 68% of the world population projected to live in urban areas by 2050, says UN Avaliable at: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html#:~:text=News-,68%25%20of%20the%20world%20population%20projected%20to%20live%20in,areas%20by%202050%2C%20says%20UN&text=Today%2C%2055%25%20of%20the%20world's,increase%20to%2068%25%20by%202050. [Acessed 14 Aug. 2020]