UNIVERSIDADE TECNOLÓGICA FEDERAL DO PARANÁ

TIBÉRIO BRUNO ROCHA E CRUZ

A CROWDSENSING TOOL FOR SMART CITIES FOCUSED ON CITIZENS ENGAGEMENT

PONTA GROSSA

2022

TIBÉRIO BRUNO ROCHA E CRUZ

A CROWDSENSING TOOL FOR SMART CITIES FOCUSED ON CITIZENS ENGAGEMENT

Uma ferramenta de crowdsensing para cidades inteligentes com foco no engajamento dos cidadão

Dissertação apresentada como requisito para obtenção do título de Mestre em Engenharia de Produção do Programa de Mestrado em Engenharia de Produção da Universidade Tecnológica Federal do Paraná (UTFPR).

Orientadora: Prof.ª Dra. Regina Negri Pagani.

PONTA GROSSA

2022

Ministério da Educação
Universidade Tecnológica Federal do Paraná
Campus Ponta Grossa

TIBERIO BRUNO ROCHA E CRUZ

A CROWDSENSING TOOL FOR SMART CITIES FOCUSED ON CITIZENS ENGAGEMENT

Trabalho de pesquisa de mestrado apresentado como requisito para obtenção do título de Mestre Em Engenharia De Produção da Universidade Tecnológica Federal do Paraná (UTFPR). Área de concentração: Gestão Industrial.

Data de aprovação: 26 de Agosto de 2022

Dra. Regina Negri Pagani, Doutorado - Universidade Tecnológica Federal do Paraná

Dr. Bruno Leopold Serge Ramond, Doutorado - Universitè de Technologie de Compiègne - Fr

Dr. Gilberto Zammar, Doutorado - Universidade Tecnológica Federal do Paraná

Dr. Joao Luiz Kovaleski, Doutorado - Universidade Tecnológica Federal do Paraná

RESUMO

As aglomerações urbanas apresentam diversas características que requerem cuidados por parte dos governantes. Uma delas é a gestão dos serviços oferecidos à população, que sempre se mostra como um constante desafio pelas frequentes ocorrências, e em diversas localidades. Monitorar essas ocorrências é tão desafiador quanto a solução desses problemas, pois demanda investimentos para o acompanhamento dos mesmos. Os recursos para esse monitoramento são escassos, e nem todos os municípios dispõem dos montantes necessários. Neste sentido, este estudo propõe uma ferramenta de gestão pública denominada DataCidade que utiliza a tecnologia de Crowdsensing, dispensando elevados investimentos, e contando com a participação e engajamento dos cidadãos para monitorizar problemas quotidianos relativos a trânsito, infra-estruturas e meio ambiente. Para dar suporte a este trabalho de pesquisa foi realizada uma revisão sistemática da literatura utilizando a metodologia Methodi Ordinatio. Procurou-se identificar aplicações e oportunidades de Crowdsensing em Smart Cities, bem como encontrar possíveis desafios, o que propiciou estruturar o aplicativo Datacidade. O DataCidade prevê que os cidadãos atuem como sensores, relatando problemas por meio do aplicativo para celular que coleta os dados e os apresenta em um painel de plataforma da web composto por um mapa de calor, gráficos de série temporal e tabelas que apoiarão a tomada de decisões.

Palavras-chave: cidades inteligentes; Crowdsourcing; Crowdsensing; aplicativo.

ABSTRACT

Urban agglomerations have several characteristics that require attention on the part of governments. One of them is the management of services offered to the population, which is always a constant challenge due to the frequent occurrences, and in different locations. Monitoring these occurrences is as challenging as solving these problems, as it requires investments to monitor them. Resources for this monitoring are scarce, and not all municipalities have the necessary amounts. In this sense, this study proposes a public management tool called DataCidade that uses Crowdsensing technology, dispensing with high investments, and counting on the participation and engagement of citizens to monitor daily problems related to traffic, infrastructure and the environment. To support this research work, a systematic literature review was carried out using the Methodi Ordinatio methodology. We sought to identify applications and opportunities for Crowdsensing in Smart Cities, as well as find possible challenges, which led to the structuring of the Datacidade application. DataCidade envisions citizens to act as sensors, reporting issues through the mobile app that collects the data and presents it on a web platform dashboard composed of a heat map, time series graphs and tables that will support decision making. decisions.

Keywords: Smart Cities; Crowdsourcing; Crowdsensing; Mobile App.

LIST OF FIGURES

LIST OF TABLES

LIST OF CHARTS

LIST OF ABBREVIATIONS

ABREPRO	Associação Brasileira de Engenharia de Produção
BD	Big Data
Ci	Number of Citation
CPF	Cadastro de Pessoa Física
GDP	Gross Domestic Product
GPS	Global Positioning System
ICT	Information and Communication Technologies
IF	Impact Factor
IoE	Internet of Everything
IoT	Internet of Things
IoV	Internet of Vehicles
JCR	Journal Citation Reports
MG	Main Goal
RFID	Radio Frequency Identification
SDG	Sustainable Devolopement Goals
SG	Specific Goals
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization

SUMMARY

1 INTRODUCTION

The world population is projected to grow to a staggering 9.7 billion people by the year 2050 and 10.9 billion in 2100 (OUR WORLD IN DATA, 2021). Even though the growth rate has decreased from 2.1% in 1968 (highest) to 0.1% in 2100, the numbers are already high enough for us to be concerned with our future.

The UN has stated that, by the year 2050, 68% of the world population is predicted to be living in urban areas. And, as the population grows, resources will become more and scarcer. Thus, providing food, space for housing and industries, and resources to supply human and economic activities for over 6.5 billion people in a sustainable manner is definitely a challenge. So, a smarter way to manage urban areas becomes paramount.

For these reasons, there is a growing concern on how to make cities a better place to live, besides pondering on how to develop commercial and industrial activities. Thus, elements related to technology, people, and community, such as infrastructure, mobility, economy and environment, are some of the issues that need improvement (NAM; PARDO, 2011). In this context, the term Smart City arises as a way to foster the necessary improvements that a city needs, aided by technology.

There are many different conceptions of Smart Cities, mainly relating to technology, urban infrastructure, and people (PAGANI *et al*., 2022) and, among them and as a summary of them all, a Smart City can be understood as the one able to deal with everyday problems more readily (ALBINO; BERARDI; DANGELICO, 2015).

Although there are many definitions as to what constitutes a Smart City, Nam and Pardo (2011) name three recurrent components: (i) instrumentation, that is, the sensors, hardware and equipment in general to monitor a city; (ii) interconnectivity, representing the network for communication between devices and people; and (iii) intelligence to use the collected data effectively for smart decision-making.

Out of those three components, this study aims to address the challenges that instrumentation and intelligence may pose to cities where there is no technological structure or financial resources to equip the city and where there is a lack of citizen engagement. Among the necessary tasks that must be performed in a Smart City, collecting data and information is essential.

Cities’ problems that require information gathering can come in the form of a small crack on the asphalt, systemic sanitation problems or even environmental ones such as selective waste collection and pests. There are also traffic, public transportation, energy supply, infrastructure, and healthcare issues, among others. These are hard to monitor everyday problems, and collecting data from all these sources may prove to be a big expensive challenge.

Therefore, collecting data has become one major issue, especially in the Era of Big Data. It is neither an easy strategy nor a cheap one. The use of sensors and similar devices to collect data can be costly and requires huge work with maintenance, therefore making projects unfeasible to certain economic realities.

So, due to the high costs and complex operations, it is important to find options that could optimize the data collection. And even though there are many devices suited for these activities, there is an interesting alternative that should be considered and which does not necessarily imply high investments from the government; that is Crowdsensing.

Crowdsensing techniques consist of engaging people in a given task to collect data using mobile devices (FARKAS *et al*., 2015). In the context of a city, it means using the help of citizens as sensors while collecting data that can be useful in solving urban issues regarding mobility, health, infrastructure, security, and environment, among others (GANTI; YE; LEI, 2011).

The idea of using Crowdsensing to help solve cities' problems by making them smarter has recently become a more addressed topic and approached in a much more practical manner since 2018. Practically, it means that Crowdsensing is applied to solve specific problems, such as parking, traffic, air pollution, noise pollution, and quality of life, among others. Engaging citizens as sensors rather than investing in expensive hardware might prove to be more economically feasible, additionally broadening their participation in actions from the government.

That is where the idea of the tool proposed in this work emerges, in the format of a project composed of a mobile phone app where citizens would be able to input data regarding cities’ issues. However, the challenge does not stop at the data collection part; it is necessary to work with this data in a practical and useful manner, and for that, a real-time dashboard could present the inputted data visually. The app is for the citizens to interact with, and the dashboard is for the city’s planners and stakeholders to draw insights from.

Scarcity being the motif of this project's proposal, it is important to assess if the proposed tool fosters sustainability, and for that, the 17 SDGs will serve as a reference, as well as the smart city pillars.

1.1 Research problem

Cities will play a major role in societies as urban living continues to grow. They are the place where everyday life happens, regarding the professional and personal aspects of all citizens. Thus, it is also where many problems of different dimensions can be identified. Governance is constantly requested to solve these problems, but it always struggles with budget barriers.

Nevertheless, knowing which ones are priority over the others in real-time is also a major challenge. This is where the research question of this work arises: How can a city's governance monitor the problems related to public services without investing large amounts of money on infrastructure? Based on this start question, we pose the following research goals.

1.2 Goals

1.2.1 Main goals (MG)

The main goal of this research is to propose a Crowdsensing tool for cities management.

In order to support this proposal, five specific goals are set.

1.2.2 Specific goals (SG)

- SG1: To survey the main Crowdsensing applications in Smart Cities;
- SG2: To analyze how these Crowdsensing applications support the six Smart Cities' pillars;
- SG3: To structure a Crowdsensing tool to monitor major cities' problems regarding urban planning and maintenance;
- SG4: To discuss how the project can support the Smart Cities pillars and the Sustainable Development Goals.

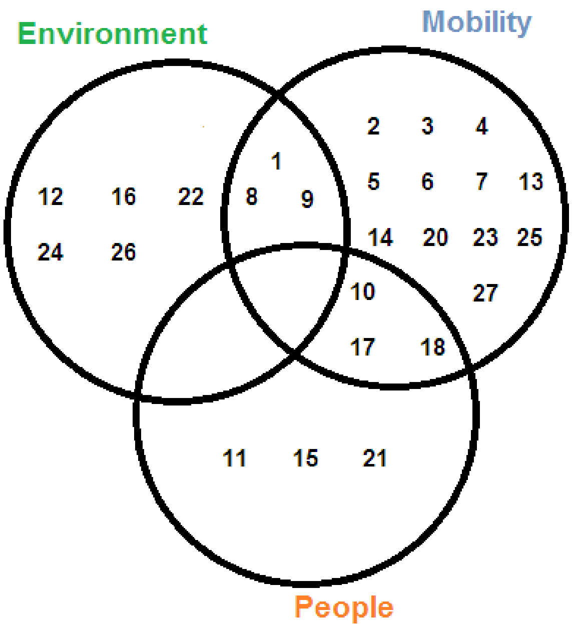
1.3 Justification

Academic and technological advances are only relevant if they are realistic. There are a plethora of solutions for cities' problems that rely heavily on technological investments. However, cities are human settlements present all over the world, and most of the world does not have the economic conditions for such investments.

For instance, if you compare the Gross Domestic Product (GDP) per capita of Western Europe in 2015 of 40175U$ with the GDP per capita of Latin America of 14400U$ in the same year, this difference is evidence of how far economically cities can be. Therefore, alternatives must be at hand when dealing with such barriers, and one valuable alternative is citizen engagement and participation. In this context, this study contributes to four major areas: (i) academic; (ii) social; (iii) economy; (iv) governance.

i. *Academic contribution*: Despite Crowdsensing being a versatile and adaptable strategy, nevertheless, literature has proven it does not cover all Smart Cities pillars, as illustrated in Figure 1. The pillars of a smart city are: Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environment and Smart Living (CORSI *et al*., 2020). The illustration shows three of the six Smart Cities pillars. The numbers inside the circles represent the numbers of articles in this research portfolio which are addressing the respective pillar. The Numbers located in the intersections of the circles mean that that article attends both pillars. It is possible to observe that there is not any article linking people and environment, and none in the center connecting the three pillars, addressing all the three pillars. Therefore, this study contributes to the academy by highlighting the gap in Crowdsensing applications in Smart Cities, providing a link between the three pillars. Furthermore, it addresses the six pillars of a smart city.

Figure 1 - Articles by pillars



Source: Elaborated by the author (2022)

ii. *Social contribution*: This study contributes socially by fostering citizen engagement and sustainability. When the smart city concepts started being proposed, they had a more technocentric focus, discussing mainly technology and infrastructure. Gradually, the anthropocentric focus is emerging, and people started to have a more highlighted role than before (PAGANI *et al.*, 2022). However, citizen participation is still an unexplored asset in Smart Cities, as highlighted by Granier and Kudo (2016), pointing out the lack of engagement and the weakness of practices by citizens. DataCidade aims to direct the focus to citizen engagement and participation. According to Sun *et al.*, (2016), the objectives of smart communities are to remember the past, live in the present, and plan for the future. These goals make up the vision of an intelligently connected community. The lack of community values such as respect, engagement, sense of identity, and belonging (RACO, 2007), discourages the preservation of cultural and natural heritage, therefore failing to improve habitability and sustainability. In this context, DataCidade is preservation to remember the past; habitability to live in the present; sustainability to plan the future. The proposed tool might promote citizenship in communities. This can also lead to social cohesion and increase the feeling of belonging to a local community. This study will attempt to match the solutions that the tool covers with the 17 Sustainable Development Goals (SDGs) set by the UN;

iii. *Economic contribution*: It is easier to make cities smarter if there are financial resources to do so; however, that is not the case for most of the world. Crowdsensing in Smart Cities can be a powerful technique to foster feasibility; this means that projects that aim for improvements in sound and air pollution monitoring, mobility, and quality of life improvements, environmental solutions, among others, might otherwise not be possible to implement if high investments in hardware for monitoring are necessary. Even though DataCidade does not have a direct application to the economy, it was conceived seeking to fill the gap of not having financial conditions to implement smart solutions;

iv. *Contribution to the government*: This study carries relevance for governance by proposing a tool to improve decision-making in cities. It consists of a mobile phone app that collects data from citizens and presents it in the form of charts, tables, and a heat map that makes up a dashboard. The data collected points to problems and opportunities for local governments concerning the environment and urban infrastructure. Citizens will voluntarily participate by providing information about issues that disturb everyday life. This way, DataCidade might help city planners develop accurate solutions, creating a stronger bond between citizens, government, and the city.

1.4 Production engineering and the proposed research theme

There are 12 main areas, each with particular sub-areas, in Production Engineering according to the Brazilian Association of Production Engineering (ABEPRO), as detailed in Annex A.

The tool DataCidade is able to embody concepts of Crowdsensing, Statistics, and Data Science all applied to Smart Cities, approaching a wide variety of areas and subareas preconized by ABEPRO. Due to its characteristics, the application is open to adaptation, meaning that the data collected can be of various natures for different purposes. Chart 1 shows the areas and subareas tackled by DataCidade.

Chart 1 - Areas and subareas addressed by DataCidade

Area	Subarea
7. STRATEGIC AND ORGANIZATIONAL MANAGEMENT	7.2. Strategic planning
8. ORGANIZATIONAL KNOWLEDGE MANAGEMENT	8.3. Production Information Management 8.3.1. Management Information Systems 8.3.2. Decision Support Systems
9. ENVIRONMENTAL MANAGEMENT	9.1. Natural Resource Management 9.2. Energy Management 9.3. Industrial Waste Management
12. SUSTAINABILITY AND SOCIAL RESPONSIBILITY	12.1 - Sustainability Indicators 12.2 - Social Responsibility Indicators 12.3 - Sustainable Development and Production Engineering

Source: Elaborated by the author (2022)

The data collected by DataCidade at the moment that this study is being carried out focuses on urban infrastructure and the environment; it approaches the areas and subareas shown in Chart 1.

It enhances the strategic aspect of area 7 since its final product is a dashboard that improves decision-making; it covers area 8 as it is a technological innovation directed at city management; it addresses area 9 because it collects data that helps monitor the quality and safety of the environment; area 12 represents the core purpose of DataCidade and what it seeks to achieve: sustainability.

1.5 Structure of the work

This work is divided into five sections. The first one contextualizes the theme and presents the problem involving it, the objectives to be reached, and its justification. Section 2 approaches the theoretical background, depicting the themes of Smart Cities, Crowdsourcing and Crowdsensing, and sustainable development goals.

Section 3 describes the methodology applied, explaining how the theoretical background was built and how the tool was structured. Section 4 presents the results, and the discussions were done. Finally, Section 5 presents the conclusions.

2 THEORETICAL BACKGROUND

This Section exposes the theoretical background and concepts that surround this study; they are Smart Cities (2.1), Crowdsourcing and Crowdsensing (2.2), and the Sustainable Development Goals (2.3).

2.1 Smart Cities

With the increase in urban population, intensified by the influence of globalization (HEATON; PARLIKAD, 2019), about half of the world's population is living in cities (CAMERO; ALBA, 2019), and this proportion is likely to be even higher in the coming years, It is estimated that 60% of the world's population will live in urban areas by the year 2030 (UN DEVELOPMENT PROGRAMME, 2018).

With the growth of the flow of people in cities, there is also an increase in the challenges to be faced, such as pollution, health problems, and traffic flow, among other issues (FULMAN; BENENSON, 2017). In the midst of this context, Smart Cities emerge with the objective of improving life quality and environmental protection (KUMMITHA; CRUTZEN, 2017).

The term Smart Cities began to be used approximately in 2010 with the emergence of projects related to this theme, which received support from the European Union (AHVENNIEMI *et al*., 2017).

Since then, several authors have started to research and write about the topic, trying to define it and better understand its scope. In Chart 2, it is possible to observe some of these definitions that also cover the objectives of Smart Cities.

Chart 2 - Definitions and objectives of the Smart Cities

Authors	**Definition**
Kummitha and Crutzen (2017)	Smart Cities are geographic environments in which digital services are applied, aiming at environmental protection and citizens' quality of life.
Adapa (2018)	Smart Cities seek solutions for better management of cities, taking into account the population's quality of life.
Li *et al*. (2019)	Smart City aims at solutions to improve competitiveness and economic growth through the use of technologies which promote efficiency for urban areas.
Hîrţan, Dobre and González-vélez (2020)	Smart Cities interconnect various data sources and technologies so that cities can integrate homes, public service networks, and public transport management, transforming the city into a functional ecosystem with increased accessibility and quality of life for citizens.
Shahrour and Xie (2021)	The Smart City emerged through the use of Information and Communication Technology, with the aim of improving the quality

	of life of citizens and dealing with urban environmental, social and economic challenges.

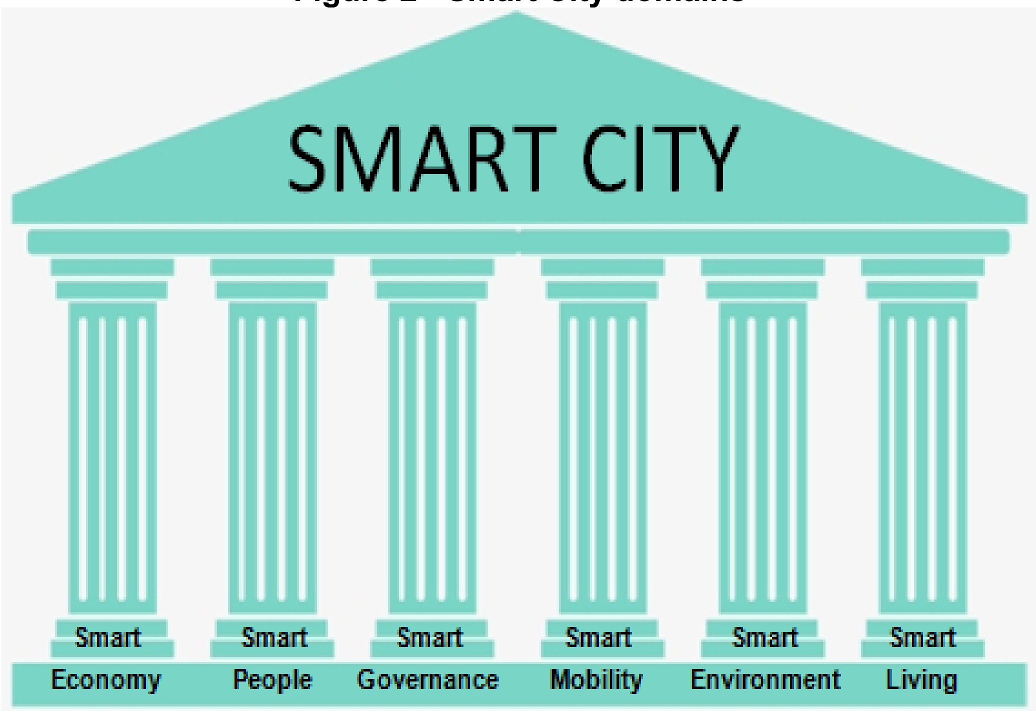
Source: Elaborated by the author (2022)

Various concepts and definitions have been proposed for the smart city, and some of these concepts are holistic and based on social innovation and the use of ICT aiming to improve the quality of life and services in the city (SHAHROUR; XIE, 2021).

Chart 2 gathered only some of these definitions, seeking to show that the focus is usually on sustainability, quality of life for citizens, economic development and use of technology, and this focus has been maintained over the years by researchers.

But it is clear that such a broad concept can be better understood and applied when partitioned, so, in addition to the various definitions of Smart Cities available in the literature, it is also possible to find the concept of some domains, namely: Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environmental, and Smart Living, as illustrated in Figure 2, and are described below:

Figure 2 - Smart City domains



Source: Adapted from Corsi *et al.* (2020)

Smart Economy: the working scheme of the economy tends to undergo adjustments over the years; therefore, the Smart Economy is characterized as an environment in which economic phenomena occur (KIM; JUNG, CHOI, 2016), aiming at the efficient use of resources through technological innovations (IGI GLOBAL, 2022), in addition to using data to assist in decision making, allocate resources efficiently and allow cooperation between various domains, facilitating e-business, e-commerce and new opportunities for entrepreneurs (CARAGLIU; NIJKAMP, 2011). Therefore, the economy becomes really smart when it manages to balance costs and benefits, allowing competitive performance and innovative entrepreneurial activities. (BALACEANU; TILEA; PENU, 2017; POPOVA, 2020; TUREČKOVÁ; NEVIMA, 2020).

Smart People: represents the people who need to exist for the Smart City to make sense; for that, it is necessary to take into account human resources, capacity management, participation in public life, involvement with society, development of professional skills and abilities, and the handling of technologies (BATES; GUPTA, 2017; GURASHI, 2018; POURNARAS; YADHUNATHAN; DIACONESCU, 2020).

Smart Governance: supports the development of a transparent, inclusive system of governance based on public participation (SHAHROUR; XIE, 2021), aiming at an interrelationship between State, civil society and the market to achieve economic, social and institutional development in a stable way (GIULIODORI; BERRONE; RICART, 2022).

Smart Mobility: allows citizens to move freely within a Smart City. For this, improvements in traffic management and the study of alternative routes are necessary. With this, it becomes possible to reduce congestion and increase the satisfaction of residents and administrators of a Smart City (PAIVA *et al*., 2021), so Smart Mobility is a crucial component of the functioning of the urban environment (KARGER; JAGALS; AHLEMANN, 2021).

Smart Environmental: consists of an environment that is powered by data collected by various devices, characterized by the IoT, and through this, it is possible to provide a range of services to citizens through smart homes, smart builds and smart networks (ELMUSTAFA; MUJTABA, 2019; GANESAN *et al*., 2021).

Smart Living: is characterized by the use of smart networks by people. These people use services and are embedded in information and data-based communities such as Smart Cities. However, to be inserted into this context, citizens need to be able to handle technologies which may not be simple for everyone (CHOURABI *et al*., 2012). Smart Living requires citizens to be involved so that smart and sustainable living in the Smart City can be ensured (NIKKI HAN; KIM, 2021).

Despite the scope of the definition of the Smart Cities concept and its domains, it is possible to perceive that Smart Cities are closely related to the use of technologies to achieve the various objectives in cities; the following Subsection presents some of these technologies.

2.1.1 Smart Cities technologies

Chart 3 - Technologies in the Smart Cities

Focus	Technologies	Acronyms	Authors
Connection	Internet of Things	IoT	Atzori, Lera and Morabito (2010); Gerla *et al*. (2014); Stankovic (2014); Salim and Haque (2015); Shafique *et al*. (2018); Yin *et al.* (2020); Zhang *et al*. (2020); Enyoghasi and Badurdeen (2021).
	Internet of Everything	IoE	Bojanova, Hurlburt and Voas (2014); Charmonman and Mongkhonvanit (2015); Salim and Haque (2015); Auger, Esposito and Lochin (2018); Di Martino *et al*. (2018); Srinivas, Jabbar and Neeraja, (2018); Yu *et al*. (2018); Xu *et al*. (2019); Evans (2012).
	Internet of Vehicles	IoV	Gerla *et al*. (2014); Yin *et al*. (2020)
Data	Big Data	BD	Akram *et al*. (2019); Qader, Ameen and Ahmed (2020); Jezdović *et al*. (2021).
Computing	Cloud Computing	-	Foschini *et al.* (2021); Zou *et al.* (2021).
Data collection	Sensors	-	Ramírez-Moreno *et al.* (2021); Hancke *et al.* (2012).
Identification	Radio Frequency Identification	RFID	Hähnel *et al*. (2004); Atzori, Iera and Morabito (2010); Salim and Haque (2015).
Location	Global Positioning System	GPS	Ganti; Ye and Lei (2011); Singh, Bansal and Sofat (2017); Salim and Haque (2015).
Information	Information and Communications Technologies	ICT	Silva *et al*. (2019); Foschini *et al.* (2021).
Collaboration	Crowdsourcing / Crowdsensing	-	Montori, Bedogni and Bononi (2018); Staletić *et al*. (2020).

Source: Elaborated by the author (2022)

The various technologies were divided into eight classifications, namely: connection, data, computing, data collection, identification, location, information and collaboration, and are described below.

Internet of Things (IoT): refers to the use of computing devices to identify and connect a series of everyday objects to the internet, even being attached to animals and people (SALIM; HAQUE, 2015). In this way, the IoT represents a network in which sensors and objects are connected and controlled and can also be monitored from anywhere and at any time (ATZORI; LERA; MORABITO, 2010; ENYOGHASI; BADURDEEN, 2021; ZHANG *et al*., 2020).

Present in cars, homes and smartphones, IoT represents an autonomous and intelligent solution that allows organizations, cities and other groups to respond to their demands efficiently (STANKOVIC, 2014; SHAFIQUE *et al*., 2018).

Internet of Everything (IoE): While IoT is a dynamic global network infrastructure focused on making devices accessible over the Internet, IoE has a broader focus, being concerned with smart network connections and technologies (XU *et al*., 2019; SRINIVAS; JABBAR; NEERAJA, 2018; DI MARTINO *et al*., 2018; BOJANOVA; HURLBURT; VOAS, 2014).

The term Internet of Everything began to be used in 2012 by CISCO (EVANS, 2012), a technology company, as a network of networks that aims to bring together people, data and processes in network connections (CHARMONMAN; MONGKHONVANIT, 2015; YU *et al*., 2018; AUGER; ESPOSITO; LOCHIN, 2018).

Internet of Vehicles (IoV): The technological revolution brought about by the IoT affected several areas, such as the field of vehicles, where the concept of IoV emerged, representing an integrated network composed of vehicles and users (GERLA *et al*., 2014). In this context, a vehicle has computing, sensing and storage resources, with the objective of improving the quality of life of people in Smart Cities through the collection of data generated by vehicles (GERLA *et al*., 2014), contributing to a more efficient vehicle flow.

Big Data (BD): Due to a large amount of data generated through the use of various devices, the term Big Data has come to be used to refer to this continuous generation of data (AKRAM *et al*., 2019). Some characteristics were raised to classify a large amount of data in Big Data: volume, speed, variation, veracity, value, and volatility, among others (AKRAM *et al*., 2019; QADER; AMEEN; AHMED, 2020).

As technologies capable of analyzing this data improve, many insights can be used in the areas of management and decision-making, for example (JEZDOVIĆ *et al*., 2021). Smart Cities present an interesting environment for the generation and collection of Big Data (ZHU *et al*., 2018).

Cloud Computing: is an on-demand access network model used to share computing resources (ZOU *et al*., 2021). By sharing these resources, such as storage capacity and data analysis, the Smart City can benefit from a wider range of city services, such as transportation, water and energy supply, and public health (FOSCHINI *et al*., 2021).

Sensors are important devices of a Smart City, as they are responsible for collecting data in real-time. This data can be transformed into valuable information for city management and citizens' well-being (RAMÍREZ-MORENO *et al*., 2021). Authors such as Hancke et al. 2012, write about Smart Sensors, a breakthrough in sensors to collect data and keep the city connected.

Radio Frequency Identification (RFID): commonly used in the form of a tag, RFID was one of the first enablers of the IoT because this technology offers the possibility of uniquely identifying and tracking users (HÄHNEL *et al*., 2004; ATZORI; IERA; MORABITO, 2010).

Global Positioning System (GPS): Used to collect information about the displacement of a device, GPS is able to provide information about the latitude and longitude of a given location. This technology is available in cell phones and other technological tools (GANTI; YE; LEI, 2011; SINGH; BANSAL; SOFAT, 2017). With this, a lot of data can be collected regarding the daily commuting activities of users (SALIM; HAQUE, 2015).

Information and Communications Technologies (ICT): various sensors, devices, systems and objects have been connected with the growth of ICT, which are characterized by technologies that are capable of transmitting the information. In the Smart Cities scenario, ICTs are necessary for helping to build more efficient urban planning, which allows decisions to be made before problems occur (SILVA *et al*., 2019).

It can be said that the concept of Smart Cities emerged in a context of great disruptive innovation caused by ICT. Since then, its focus has been on improving the quality of life in cities and solving environmental, social and economic challenges in urban environments (NAPHADE *et al*., 2011; POURYAZDAN; KANTARCI, 2016; SHAHHOUR; XIE, 2021). Therefore, Smart Cities use ICT with the aim of enriching public services and the quality of life of citizens (FOSCHINI *et al*., 2021).

Crowdsensing: sensing processes are considered an important way of capturing data in a Smart City (ALVEAR *et al*., 2018). This is because through sensors already available on mobile devices used by people, a lot of data can be collected, allowing the detection of potential dangers for citizens (MONTORI; BEDOGNI; BONONI, 2018) to be perceived in the environment.

As one of the main topics covered in this dissertation, Subsection 2.2 is dedicated to addressing in more detail the definitions, characteristics and involvement of people in the Smart Cities and Crowdsensing context.

2.2 Crowdsourcing and Crowdsensing

The concept of Crowdsourcing has been gaining popularity in recent years, and its application within Smart Cities has shown to be very promising in relation to e-participation (SWAPAN, 2016), that is, participation that takes place online. In this way, Crowdsourcing can be seen as a business model based on interactive platforms available on the internet (STALETIĆ *et al*., 2020).

In this model, there are some data buyers, called crowd sourcers, and data sellers, known as contributors (YANG *et al*., 2016). Crowdsources outsource the detection and data capture tasks to a multitude of contributors, who in turn provide the data and information needed to complete a task in exchange for a reward (CHAKERI; JAIMES, 2018).

This data collection process can be done through the various smartphones currently available in the hands of citizens. The tasks to be performed are broad, but some examples would be collecting data related to monitoring urban traffic, weather and public safety (HOFBAUER; SIGMUND, 2003; CHAKERI; JAIMES, 2018). At the same time, the reward of this participation can be the acceleration of the availability of smart services and quality of life for citizens through the integration of smartphones and the active participation of people in the Smart Cities ecosystem (LEE; HOH, 2010; CHAKERI; JAIMES 2018).

Related to the concept of Crowdsourcing arises the concept of Crowdsensing, which can be considered as a subtype of Crowdsourcing in which the sensors are the real sources of the collected data (GANTI; YE; LEI, 2011; ALVEAR *et al*., 2018). While crowdsourcing aims to use collective intelligence to solve complex problems by dividing them into smaller tasks that are performed by the crowd (contributors), crowdsensing shares the responsibility of collecting information with the crowd, focusing mainly on urban monitoring (CARDONE *et al*., 2013).

In this way, Crowdsourcing can be summarized as the performance of a specific task, and possibly with a determined time to be completed, while Crowdsensing seeks to collect data on a continuous basis, aiming at monitoring a daily situation.

Therefore, Crowdsensing, also known as Participatory Sensing or Community Sensing, aims at the collective sharing of data, which enables the extraction of information capable of mapping situations of common interest through sensing and computing devices (GANTI; YE; LEI, 2011). Chart 4 brings together some more of the Crowdsensing definitions found in the portfolio of articles for this dissertation.

Chart 4 - Crowdsensing definitions

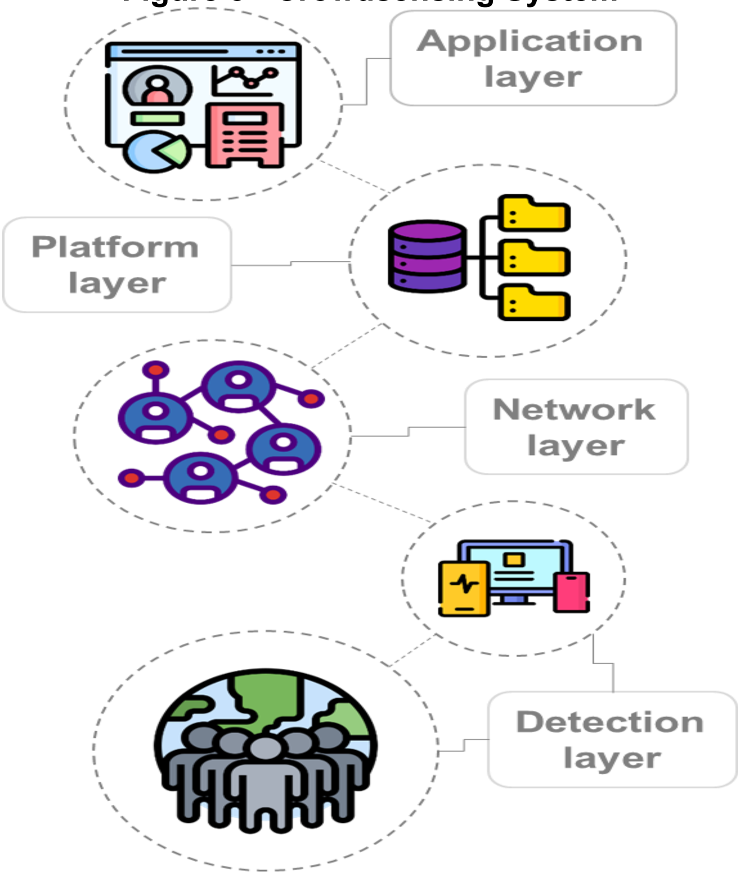
Definitions	Authors
Crowdsensing can be considered a technological enabler for Smart Cities, with the aim of improving the quality of sensing through mobile devices, validating the data collected and promoting active citizen participation.	Ganti, Ye and Lei (2011) Talasila, Curtmola and Borcea (2013)
Crowdsensing represents a new scheme of collective sharing of data and information for mapping phenomena of common interest through mobile devices.	Ganti; Ye and Lei (2011)
Crowdsensing involves citizen participation through the use of mobile devices that provide data through the sharing of photos, sounds, location and others.	Chakeri and Jaimes (2018)
Crowdsensing aims to promote the involvement of citizens through the reporting of situations, generating data without the need to deploy monitoring sensors directly at the sites, as most sensors are already available on smartphones, having the advantage of low cost and providing data in real-time.	Montori, Bedogni and Bononi (2018)
Crowdsensing performs the process of outsourcing the task of sensing to a large number of people who have a mobile device, making it possible to capture information through sensors of acceleration, temperature, microphone, gyroscope, and camera, among others.	Capponi *et al*. (2019)
With the use of Crowdsensing technology, it is possible to obtain a greater understanding of the environment in which citizens are inserted, increasing people's awareness of urban challenges, such as noise reduction.	Liu, Kong and Chen (2019)
Crowdsensing seeks to offer benefits in terms of data accuracy and lower deployment cost, but it also presents some challenges, especially regarding data security.	Sucasas *et al.* (2020)

Source: Elaborated by the author (2022)

According to the definitions of the various authors, it is possible to perceive that Crowdsensing emerged with the objective of being another facilitating technology for the promotion of Smart Cities through a new way of capturing data. In addition, the focus on citizens and mobile devices is perceived in most definitions, making clear the interconnection between city, person and technology.

According to Liu, Kong and Chen (2019), a crowdsensing system consists of four layers, namely: detection, network, platform and application, as illustrated in Figure 3, and are described below:

Figure 3 - Crowdsensing System



Source: Elaborated by the author (2022)

- *Detection layer* (data collection): citizens use their mobile devices to collect data;
- *Network layer* (data transfer): the transfer of collected data is carried out over a network, e.g. a cellular network, Wi-Fi network or a sensor network.
- *Platform layer* (data grouping): data are grouped on a platform, which will store this data for use in the next layer;
- *Application layer* (data processing and analysis): in this layer, data is processed and analyzed and can be useful for monitoring different urban situations, such as traffic monitoring and air quality monitoring, for example.

With all these layers in place, Crowdsensing can offer many benefits in terms of data accuracy, the possibility of real-time collection, and the reduced cost of deployment, as it does not need dedicated sensors for the data collection task. But takes advantage of sensors that already exist in mobile devices (SUCASAS *et al.*, 2020).

However, some challenges arise when it comes to data manipulation, which is no different in the context of Crowdsensing. The reliability of data, in relation to their availability, is pointed out by Montori, Bedogni and Bononi (2018), while the security of these data is identified as a critical issue by Sucasas *et al*. (2020).

Even with some challenges still requiring further studies, the use of Crowdsensing offers the possibility of carrying out the monitoring of several areas, such as noise measurement (CAPPONI *et al*., 2019; LIU; KONG; CHEN, 2019), detection of environmental variables, such as pollution, pollen and temperature (ALVEAR *et al*., 2018; CHAKERI; JAIMES, 2018) and traffic detection (WAZE, 2022), among others.

These areas are related to urban monitoring, where citizens are inserted and using their smartphones, which among mobile devices can be considered the most common; therefore, the next Subsection 2.2 the use of smartphones for data collection.

2.2.1 Mobile Crowdsensing

Crowdsensing is characterized by the massive use of mobile devices that are able to collect diverse information on a global scale through people willing to collaborate with the continuous process of data collection (CARDONE *et al*., 2013). Therefore, the term Mobile Crowdsensing (MCS) came to be used to further highlight the “mobile” characteristic of devices, especially smartphones, which have sensors or are able to access online platforms (LIU; KONG; CHEN, 2019).

Due to the detection power and ubiquity obtained with the use of mobile devices, MCS has emerged as an emerging concept in Smart Cities, aiming to capture phenomena of common interest within a society (OGIE, 2016; CHAKERI; JAIMES, 2018). Thus, Smart city sensing needs MCS to better take advantage of mobile devices, which are equipped with various sensors (POURYAZDAN *et al*., 2017).

As one of the main objectives of the Smart City is to integrate the physical world with the virtual world (BORGIA, 2014), it is necessary that environmental and behavioral sensing resources are added to cities in order to allow the capture and analysis of real-world data (ALVEAR *et al*., 2018), in this sense, MCS can be a good option, and has been widely used within Smart Cities (SÁNCHEZ-CORCUERA *et al*., 2019).

Within this context, smartphones are highlighted for being present in the daily lives of citizens, being used to access social networks, record videos and take photographs among many other functions made possible by the many applications available on these devices (LIU; KONG; CHEN, 2019).

And as smartphones become more efficient with their sensing technologies, the more MCS becomes a low-cost option for large-scale data collection (CHEN *et al*., 2020). In the literature, it is possible to find some definitions for the MCS; therefore, Chart 5 brings together some of these definitions found in the portfolio of articles.

Chart 5 - Mobile Crowdsensing definitions

Authors	Definitions
Mobile Crowdsensing seeks to connect a large number of mobile devices that have sensors, providing ubiquitous and decentralized services and applications in the Smart Cities scenario.	Gupta *et al*. (2012)
Mobile Crowdsensing is a technology that seeks to take advantage of a crowd of people with their mobile devices to collect data almost for free.	Farkas *et al.* (2015)
Mobile Crowdsensing has become a very promising data detection model in taking advantage of mobile workers, that is, mobile devices, to perform various tasks over wireless networks.	Guo *et al*. (2015)
Mobile Crowdsensing aims to take advantage of a large amount of data available with the exponential growth in the number of mobile devices available worldwide, thus enabling citizens to contribute to the generation and detection of data.	Guo *et al.* (2016)
In Mobile crowdsensing, citizens can contribute to the generation of data through mobile devices, such as smartphones and tablets.	Fiandrino *et al.* (2017)
Mobile Crowdsensing allows the collective and continuous collection of data through sensors, processors and storage available on mobile devices.	Hîrţan, Dobre and González-vélez (2020); Boubiche *et al*. (2019)
In Mobile Crowdsensing, it is possible to exploit the sensors embedded in smartphones to collect large amounts of data in wide regions.	Belli *et al*. (2020)
Mobile Crowdsensing can be considered a very effective approach to enabling large-scale sensing. As the main feature, Mobile Crowdsensing presents the participation of citizens through mobile devices, not depending on dedicated sensors, which reduces the cost of deployment.	Zhu, Zhang and Niyato (2021)

Source: Elaborated by the author (2022)

As highlighted by the authors in some of the definitions, one of the biggest advantages of MCS is the possibility of collecting a large sample of data, thanks to a large number of mobile devices available for this, thus allowing observations of urban phenomena to be carried out (TALASILA; CURTMOLA; BORCEA, 2015; FOSCHINI *et al*., 2021).

To illustrate in practice how the MCS works, we can observe the company Google that explores information about the location of smartphones in order to offer the monitoring of road congestion situations (GOOGLE INC., 2016), which can be accessed by a smartphone with Internet access.

In this sense, citizens play a fundamental role in collecting data through photos, sounds, temperature detection and location (CHAKERI; JAIMES, 2018), so their participation is very important in the context of the MCS and can be divided into two classes: participatory and opportunistic (GUO *et al*., 2014; MONTORI; BEDOGNI; BONONI, 2018; DASARI *et al*., 2020).

In the participatory contribution, participants need to consciously feed a data collection platform; that is, at some point, the user will open this application on their mobile device and enter the data they want there, choosing the moment they want to share data or information (GUO *et al*., 2014; MONTORI; BEDOGNI; BONONI, 2018; DASARI *et al*., 2020), as proposed in this dissertation with the DataCidade dashboard.

The same does not occur in the opportunistic contribution as data is collected in the background through sensors and applications installed on mobile devices continuously (GUO *et al*., 2014; MONTORI; BEDOGNI; BONONI, 2018; DASARI *et al*., 2020).

Once collected, these data are sent to the clustering layers and then data analysis, and as a result, citizens can receive improvements in their quality of life (ALVEAR *et al*., 2018; LIU; KONG; CHEN, 2019).

To motivate citizens to participate in the MCS process, reward programs can be developed by Smart Cities managers, in addition to the motivation that can be achieved by offering improvements in several areas for citizens (GISDAKIS; GIANNETSOS; PAPADIMITRATOS, 2014).

Therefore, observing that the use of MCS can promote greater citizen participation in Smart Cities, this dissertation also sought to relate the Sustainable Development Goals to this context, showing their relationship with the themes explained so far in the following Subsection.

2.3 Sustainable Development Goals

According to the literature, the term sustainable development gained visibility when in 1987, the report of the World Commission on Environment and Development was published, entitled “Our Common Future”, known as the Brundtland Report (WCED, 1987; BONNETT, 2013).

Since then, debates on sustainable development have been growing, largely sharing the environmental crises faced around the world (WANG *et al*., 2018), such as rising temperatures, and water and food production crises (UNESCO, 2011).

Although it is the responsibility of all people, organizations and groups to be engaged in action plans to address these challenges, the United Nations (UN) has stood out in terms of initiatives to promote actions that provide help in this context.

One of these initiatives is characterized by the Sustainable Development Goals (SDGs), which consist of objectives in several areas to be achieved by the year 2030. Some goals are interdependent and are mainly related to challenges concerning: poverty, inequality, climate change, environmental degradation, peace, and justice.

For each particular goal, there are several specific targets, meaning that they have tangible and concrete markers to be reached. The 17 overall goals are described below in Chart 6.

Chart 6 - Sustainable Development Goals

Main goals	Description
No poverty	To end poverty, everyone should have basic healthcare, security and education.
Zero hunger	Globally, one in nine people is undernourished. This goal aims to end hunger.
Main goals	**Description (continuation)**
Good health	Ensuring people live healthy lives can cut child mortality and raise life expectancy.
Education	The UN wants everyone to have access to inclusive, equitable quality education.
Gender equality	Gender equality is a human right and is vital for a peaceful, prosperous world.
Clean water	Clean water protects people from disease, yet three in 10 people lack access to it.
Clean energy	Targets for 2030 include using more renewable, affordable energy.
Economic growth	The aim is for sustainable economic growth and decent employment for all.
Industry and infrastructure	This involves building resilient infrastructure and fostering innovation.
No inequality	The poorest 40 per cent of the population should be able to grow their income faster than average.

Sustainability	The UN wants to increase affordable housing and make settlements inclusive, safe and sustainable.
Responsible consumption	This goal aims to foster eco-friendly production, reduce waste and boost recycling.
Climate action	Urgent action is needed to regulate emissions and promote renewable energy.
Life underwater	The aim is to conserve and sustainably use the oceans, seas and marine resources.
Life on land	To stop degradation, we must preserve forest, desert and mountain ecosystems.
Peace & justice	The aim is inclusive societies with strong institutions that provide justice for all.
Partnership	If all countries are to achieve their goals, international cooperation is vital.

Source: United Nations (2015)

These objectives are broad and require several actions to be achieved; therefore, in Section 4.3 of this dissertation, a parallel between the proposed DataCidade dashboard and the SDGs are discussed, aiming to promote a way to achieve part of some of these objectives in the context of the smart cities.

Therefore, this Section sought to present the main concepts that served as the basis for the development of this research, discussing Smart Cities and their technologies, in which the IoT stands out, characterized by its possibility of collecting data through different “things”.

This data, which due to its large amount, is classified as Big Data, can be captured through Crowdsensing in the context of Smart Cities, with the participation of citizens.

Thus, the objective of this research is to propose a Crowdsensing tool for city management that could be useful in the promotion of SDGs. Therefore, the Methodology Section below will explain the procedures used in the construction of this dissertation.

3 METHODOLOGY

In order to have validity, academic research needs to be replicable, meaning that if one is to follow the same steps, similar results should be found. This chapter is interested in presenting the methodology used to reach this study's results.

Thus, this chapter presents the methodological procedures used for the construction of this research, and they are divided into four Sections, which discuss the research characterization (3.1). Research organization (3.2), Elaboration of the systematic review (3.3), and Methodology for the development of DataCidade (3.4).

3.1 Research characterization

From the point of view of its nature, the research is characterized as applied. According to Gil (2008), applied research produces knowledge for practical execution and is aimed at solving specific problems. Thus, this work, besides investigating ways of using technology to foster citizen engagement in Smart Cities, also proposes an app that can be used to help map out cities' problems. The technology proposed here can be transferred to both governmental and private organizations as long as the necessary adaptations are carried out.

From the point of view of its approach, the research is characterized as qualitative (SILVA; MENEZES, 2005), as it aims to investigate, structure and propose a tool. Qualitative research provides an understanding of a given event, as the relevant aspects related to it are studied through people's perspectives and scientific discussions (GODOY, 1995).

As for its objectives, the research is classified as exploratory since, according to Gil (2008), exploratory research seeks to provide greater familiarity with the problem under study, building hypotheses and involving surveying bibliographic and practical experiences, aiming to better understand the studied variable, its meanings, its implications, among other aspects.

As for technical procedures, it is classified as experimental (GIL, 2008) since a tool is structured and proposed.

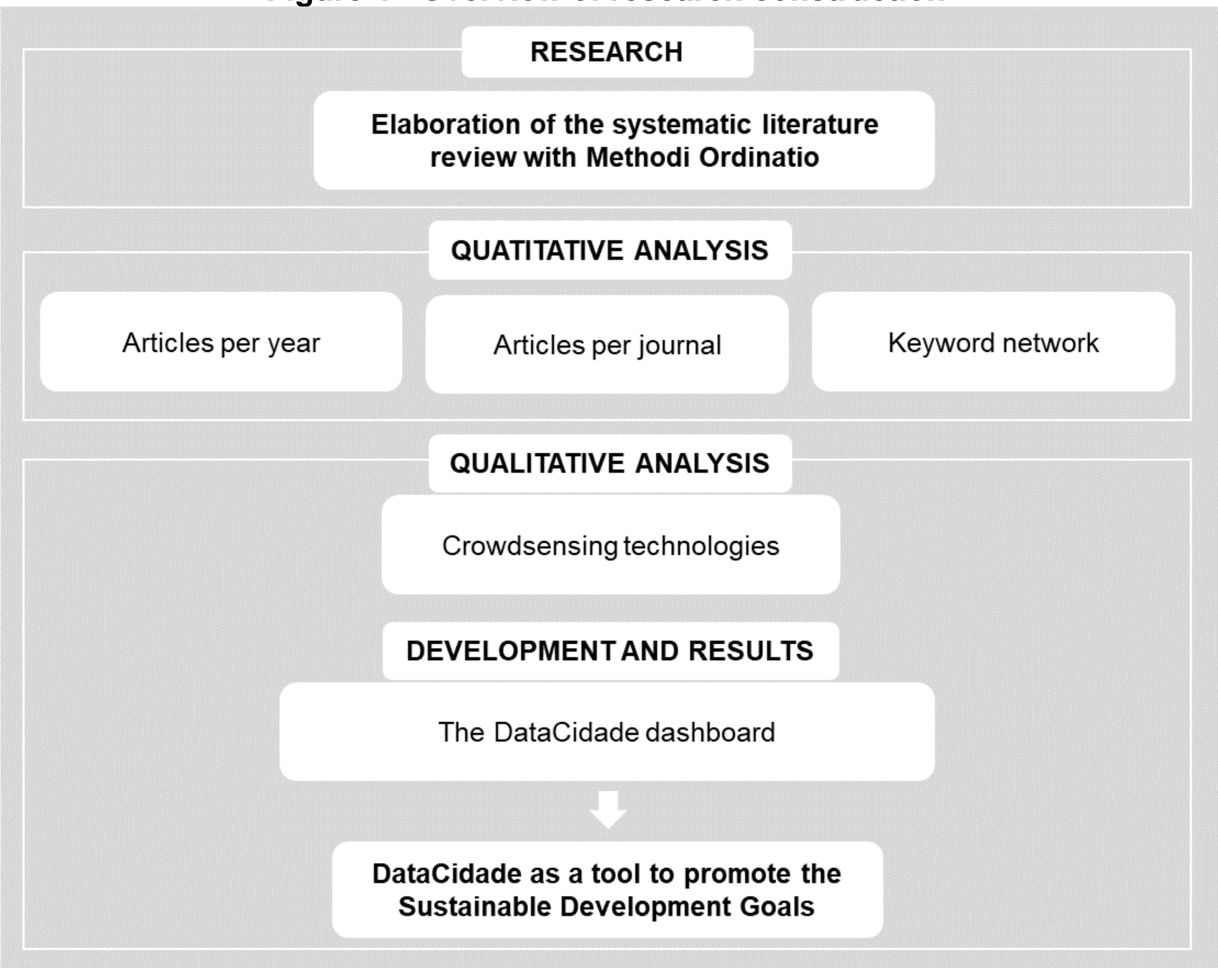
3.2 Research organization

The dissertation is organized as illustrated in Figure 4, in which a literature review was first carried out and from there it was possible to carry out a quantitative analysis of the portfolio of articles. The results of this analysis are found in Subsection 4.1.1.

Subsequently, a qualitative analysis was carried out, which sought to analyze the content of the portfolio of articles. This content was used to build Section 2, Theoretical Framework, and also to survey the technologies that were used for the development of DataCidade, as presented in Subsection 4.1.2.

In order to comply with Specific Goal 4, Subsection 4.3 discusses how DataCidade can be useful to promote the achievement of the Sustainables Development Goals (SDG).

Figure 4 - Overview of research construction



Source: Elaborated by the author (2022)

Chart 7 presents a summary of the procedures performed in the two steps of this research that are described in the following subsections.

Chart 7 - Steps of the methodological procedure

Steps	Description	Procedures	Reached goals
1 Systematic Literature Review	Elaboration of the systematic literature review	- Bibliometric; - Systematic reading and content analysis; - Problem definition and starting question; - Exploratory research on technologies for building a crowdsensing tool.	**SG1**: To survey the main Crowdsensing applications in Smart Cities
			SG2: To analyze how these Crowdsensing applications support the six Smart Cities' pillars
			SG3: To structure a Crowdsensing tool to monitor major cities' problems regarding urban planning and maintenance
			SG4: To discuss how the project can support the Smart Cities pillars and the Sustainable Development Goals
2 Development of DataCidade	Methodology for the development of DataCidade	Using the technologies found in the previous step to develop the Crowdsensing tool.	**Main goal**: propose a Crowdsensing tool for city management

Source: Elaborated by the author (2022)

As observed in Chart 7, the methodological procedures of this research were divided into two steps, which are detailed below, in the Subsections: (1) Elaboration of the systematic literature review and (2) Methodology for the development of DataCidade.

3.3 Elaboration of the systematic literature review

The methodology Methodi Ordinatio (PAGANI; KOVALESKI; RESENDE, 2015; 2018) was used to build the portfolio of scientific articles used in this research. It is a multi-criteria decision tool that allows the sorting of articles considering three variables: Year of publication, Impact factor (IF) and Citation number (Ci) of the article, which are used in the calculation of the InOrdinatio equation, in order to classify scientific articles according to their relevance.

In this way, it becomes possible to assign a value to each article individually, which, given the large number of articles resulting from the research, provides a way to select the most relevant works.

Therefore, the nine steps of Methodi Ordinatio followed in this research are described below:

Step 1 – Establishing the search intent: The necessity to have a solid theoretical basis for the development of DataCidade was what led to the research's goal. For this reason, a bibliographic portfolio on the themes of Crowdsensing and Smart Cities was built, which served as the foundations for the theoretical background of this study.

Step 2 – Exploratory research in several databases: A preliminary search was conducted in some databases. This step was carried out to investigate the possible keywords to be used later and to identify which databases returned a greater number of articles.

Step 3 – Defining the parameters for the final search: Based on the outcomes of random searches, the axis and keywords of the research were determined. Due to the intent of DataCidade being: to use citizens as sensors in order to make cities smarter, the keywords chosen were: "Crowdsensing" and "Smart Cities". The databases that found the most articles on this topic were: Scopus and Web of Science. Seeking to encompass all knowledge produced in the selected themes, no time limit is set for the research. In both Scopus and Web of Science databases, the following configuration was used: Search by title, abstract and keywords, selecting only articles and reviews, using the Boolean operator AND, and the asterisk (*) in the root of the word "city" to return all possible variations covering a larger number of articles.

Step 4 – Final research: Table 1 shows the number of papers found in each of the bases.

Table 1 - Number of articles founded

Keywords combination	**Number of articles founded**	
	Scopus	**Web of Science**
"Crowdsensing" **AND** "smart cit*"	85	79
Total of articles in both databases	**164**	

Source: Elaborated by the author (2022)

Step 5 – For this study, some research results were completely outside the scope, and no matter how keywords were used, filtering results was necessary. The researcher describes the filtering process consisting of (i) duplicate articles; (ii) type of articles (conference articles, books and book chapters); (iii) exclusion for languages other than English or Portuguese; (iv) exclusion after reading the title and abstract and, finally; (v) exclusion after reading the total paper. After this procedure was conducted, the final number of articles is shown in Table 2.

Table 2 - Number of articles deleted

Filtering description	**Number of articles deleted**
Duplicate documents	73
Type of documents	3
Language	3
After reading Title and abstract	12
After reading the total paper	2
Total articles deleted	**93**
Total article remaining	**71**

Source: Elaborated by the author (2022)

After the filtering of studies that were duplicated, document type, and exclusion after reading the title and abstract, 71 studies were left for the next step.

Step 6 – Identifying the impact factor, year and number of citations: the impact factor selected to assign importance to the journal was the JCR (Journal Citation Reports). The year of publication is collected in the article itself, and finally, the number of citations (Ci), which is found in Google Scholar.

Step 7 – Ranking of articles: This phase seeks to classify each article according to its scientific relevance, using the InOrdinatio equation (1):

$$InOrdinatio = (IF/1000) + \alpha * [10 - (ResearchYear - PublishYear)] + (Ci) \; (1)$$

Where:

- IF is Impact Fator;
- α is a weighting factor ranging from 1 to 10 assigned by the researcher, and when closer to 10, the greater importance of the current issue;
- ResearchYear is the year in which the research was conducted;
- PublishYear is the year the article was published;
- Ci is the number of citations of the article.

With the help of an electronic spreadsheet, the calculation was performed for each article and the ranking was completed, as can be seen in Chart 9 in APPENDIX A.

With the portfolio of articles ordered, it was defined as a reading criterion that all articles from the year 2020 would be read, as they may present more current technologies for the construction of the DataCidade tool.

Thus, it was established that the lowest InOrdinatio value of 2020 would be used as a cut-off line for the other articles. That is, all articles with InOrdinatio equal to greater than 80 were selected.

Step 8 – Finding the complete articles: all articles were found, totalling 56 articles.

Step 9 – Final reading of the articles: After being classified in order of relevance, the articles were read and analyzed in their entirety.

The methodology used to develop the DataCidade tool is detailed in the following Subsection.

3.4 Methodology for the development of DataCidade

The aim of this study is to propose a Crowdsensing tool for citizen engagement in Smart Cities. Citizens will participate by detecting and providing information about problems in their urban environment. This tool is called DataCidade.

The app that served as a model for DataCidade is a mobile app called Daylio. It has the proposition of asking the user to input daily information about how they are feeling according to an icon and a label and to checkmark the activities that they carried out that day. The app will create a diary of emotions and activities, relating them and giving the user the possibility of statistical analysis on how they have been feeling and what activities affect those emotions. An example of the emotion chart over time can be seen in Figure 5.

Figure 5 - Daylio chart example

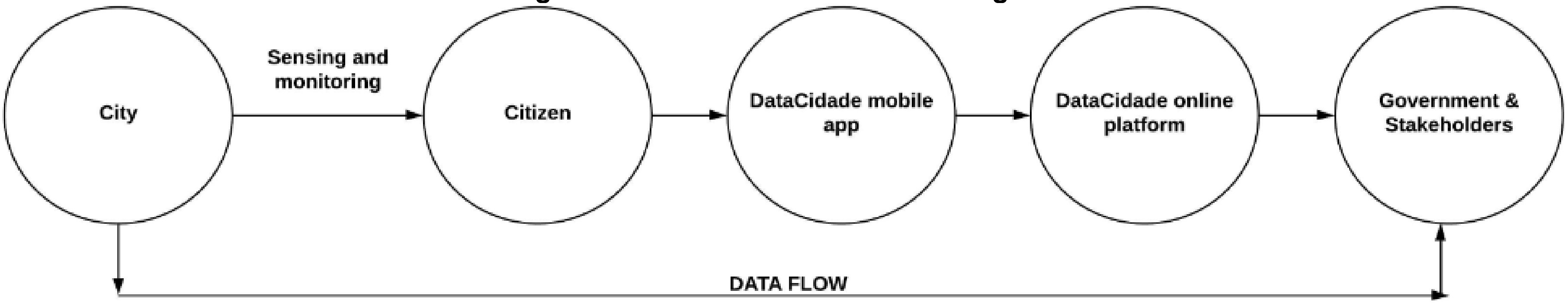
Source: Elaborated by the author (2022)

On the y-axis, there is the mood/feeling scale from bad at the bottom to happy at the top. On the x-axis is the period selected by the user. This simple architecture of collecting data from the user about his or her emotion and plotting it into a chart over time, combined with the concept of Crowdsensing and Smart Cities, was what gave birth to the initial draft of DataCidade.

While researching Smart Cities, some studies tackle the idea of monitoring citizens' emotions, feelings and mapping them. Since DataCidade is city-specific, it seemed necessary for the collected data to be also shown on a map. However, the focus of DataCidade is not on the emotions of citizens but on urban infrastructure and the environment. The collected data is not about the user, but it concerns the urban space that they live in; that is, users will sensor and monitor the city. It is well known that Smart Cities are heavily based on ICT; however, a recent trend in studies is to point out the gap between citizen engagement and participation (PAGANI *et al.*, 2019), and DataCidade fills this gap.

The architecture of collecting data from citizens, and using it to statistically map information in a useful way, made the project not only compelling but also practical in problem-solving. Figure 6 shows the data flow of the project.

Figure 6 - DataCidade's data flow diagram



Source: Elaborated by the author (2022)

First and foremost, there is data present all around the city, whether in infrastructure, the environment or other correlated issues. Citizens, as they live their everyday life, are in contact with information that can be perceived through sensing. Then, citizens are presented with the opportunity to report/collect these data.

The suggested place for this data to be inputted is the DataCidade app. After that, the data collected is organized and uploaded to a web platform to be shown as charts, graphs, and tables. Finally, the government and the stakeholders access the dashboard generated in order to take action.

4 RESULTS

In this Section, the results will be presented, and they are divided into 3 Subsections, which are (4.1) Crowdsensing in Smart Cities, addressing the quantitative and qualitative analysis of the portfolio of articles, (4.2) The DataCidade dashboard, presenting the dashboard developed to fulfil the Main Goal of this work, and finally, (4.3) DataCidade, Smart Cities domains and the SDGs, which discusses how the project can support the Smart Cities domains and the Sustainable Development Goals.

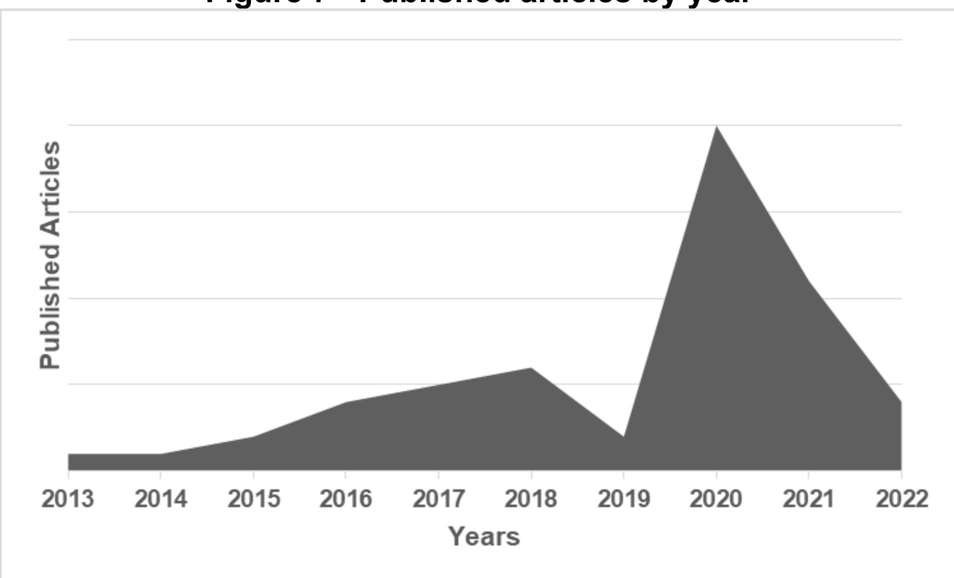
4.1 Crowdsensing in Smart Cities

The first analysis conducted was (4.1.1) bibliometrics, seeking to identify the relevance of studying Crowdsensing in Smart Cities in the present day, then the (4.1.2) main technologies in the context of Smart Cities and Crowdsensing were gathered.

4.1.1 Bibliometric analysis

The bibliometric analysis allows the vision of a quantitative overview of the portfolio of articles. Therefore, in this Subsection, the results of the bibliometric analysis of the 56 articles that make up the portfolio of this research will be presented. In order to verify the relevance of the articles present in the portfolio, the first analysis sought to quantify how many articles were published each year, as shown in Figure 7.

Figure 7 - Published articles by year



Source: Elaborated by the author (2022)

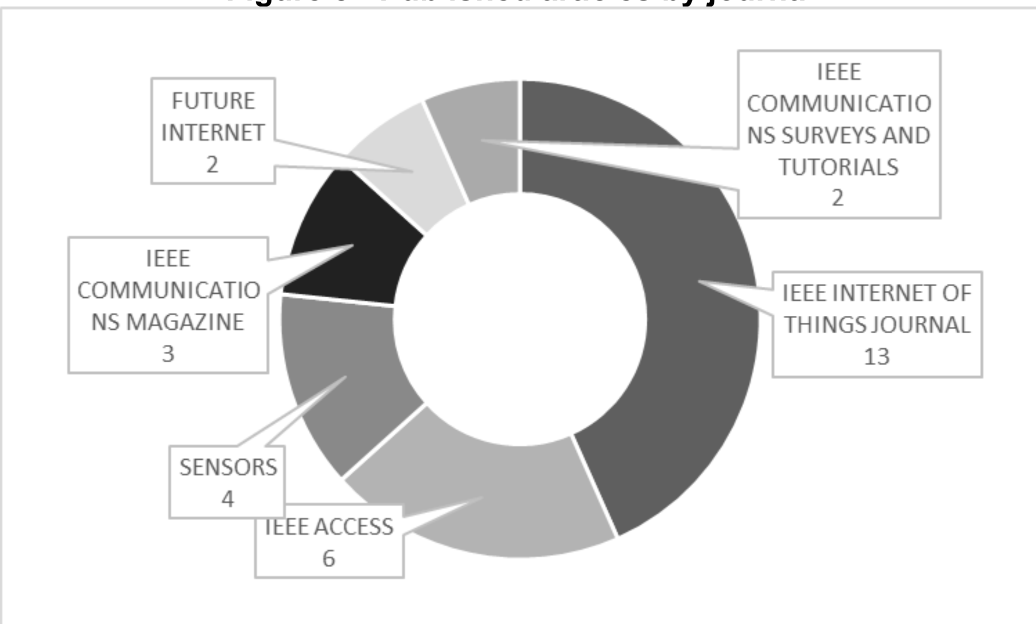
It is possible to notice that the portfolio has more articles published from the year 2020, as a result of the cut carried out through Methodi Ordinatio, described in Section 3, aiming to obtain the most current technologies in the context of Smart Cities and Crowdsensing.

However, some articles from 2013 to 2016 were also selected because they had a large number of citations and were published in journals with scientific impact measured by the metrics used in the InOrdinatio equation.

Therefore, the portfolio of articles is composed of 62.5% of articles from the year 2020, proving its relevance, but it also contains older articles, representing 37.5% of the portfolio, making it possible to explore which technologies have remained in the market. Context, as detailed in Subsection 4.1.2, in addition to bringing different definitions over the years of research on the themes, as presented in Section 2, of the theoretical framework.

To understand the distribution of research according to the journals in which they were published, Figure 8 was built, which presents all journals that had two or more articles present in the final portfolio.

Figure 8 - Published articles by journal



Source: Elaborated by the author (2022)

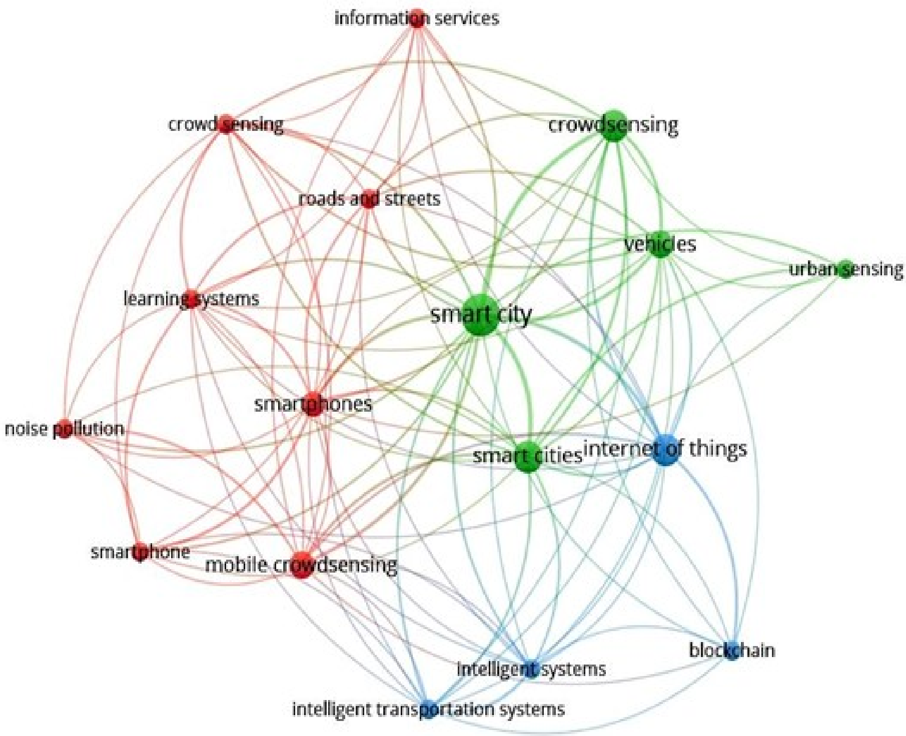
It can be noted that there is a concentration of research related to Smart Cities and Crowdsensing in Hardware and Architecture journals, such as the IEEE Internet of Things Journal, and General Engineering, such as the IEEE Access, totalling 19 articles in the portfolio.

Journal Sensors also appears in the portfolio with four articles, and its publications focus is centred on Instrumentation. While the other journals, such as IEEE Communication Journal, Future Internet, IEEE Communications, Surveys and Tutorials, focus on the area of Communications.

Therefore, it can be observed that the areas of computer science, engineering and communication intertwine to compose studies related to the two main research themes of this work.

Seeking to know which were the main keywords present in the portfolio of articles, Figure 9 was built using the VOSviewer software.

Figure 9 - Main keywords in the portfolio



Source: Elaborated by the author based on data from the databases (2022)

The most frequent keywords were: “smart city”, “Crowdsensing”, and “internet of things”, demonstrating the alignment of the chosen research methodology with the objective of this work, which is to propose a Crowdsensing tool for city management. For this, after finishing the overview of the portfolio of articles, the next Subsection

4.1.2 presents the content analysis of these articles, seeking to gather the main technologies found in the literature, which served as the basis for the construction of the DataCidade dashboard.

4.1.2 Crowdsensing technologies and the DataCidade dashboard

There are several technologies in the context of Smart Cities and Crowdsensing, as presented in Section 2 of this dissertation, in which some of the main technologies cited by the authors that are present in the portfolio of articles of this research were gathered.

Among these technologies raised during the content analysis, some were chosen to be used in the development of DataCidade and are presented in this Subsection 4.1.2.

In order to develop DataCidade, a programming language had to be chosen, and Python programming language was used by some authors, such as Silva *et al*., (2019), in which an uninformed version of the Python language was used in the development of a platform capable of estimating the amount of carbon dioxide-based on sensor readings in vehicles, in which Crowdsensing techniques and an On-Board Diagnostic (OBD-II) reader are used to extract data from vehicles in real-time, which are then stored locally on the devices used to perform data collection.

Zeng *et al*., 2020, used version 3.7.3 to propose a novel bilateral privacy-preserving and accurate task assignment framework in fog-assisted MCS, called BRAKE.

As seen, this programming language has been widely used in projects related to Crowdsensing for being efficient in these articles. Therefore, Python in version 3.9 was defined as the programming language of DataCidade.

It was also necessary to define a code interpreter, and the PyCharm IDE was selected for this, as it was developed with a focus on the Python language (https://www.jetbrains.com/pt-br/pycharm/). And to deploy the DataCidade online, the Streamlit (https://streamlit.io/) webpage was used as a platform, and GitHub was used to host the code online (https://github.com/).

Finally, the framework of useful technologies for the development of DataCidade was composed according to Chart 8.

Chart 8 - Technologies used to develop the DataCidade

Technologies	Description	Authors and References
Python	Programming language	Silva *et al*. (2019) Zeng *et al*. 2020
PyCharm	Programming language interpreter	https://www.jetbrains.com/pt-br/pycharm/
Streamlit	Platform to deploy online	https://streamlit.io/
GitHub	Online code hosting	https://github.com/
Dashboard	Classification in the literature	Gray, Obrien and Hügel (2016) Wexler, Shaffer and Cotgreave (2017) Kourtit and Nijkamp (2018) Sarikaya *et al*. (2019)

Source: Elaborated by the author (2022)

While reading the portfolio of articles, it was possible to classify DataCidade as a dashboard, which, according to Gray, Obrien and Hügel (2016), represents a possibility of visualizing, in general, a complex system which in this case is characterized by the complexity of problems. In a Smart City, which can be reported by its citizens.

A dashboard can also be described as a platform for displaying visual information, used for monitoring and understanding a scenario (WEXLER; SHAFFER; COTGREAVE, 2017; SARIKAYA *et al*., 2019), aiming at decision making and insights into a given situation. Therefore, a dashboard can be considered as an important tool for the strategic management of indicators and other information (KOURTIT; NIJKAMP, 2018).

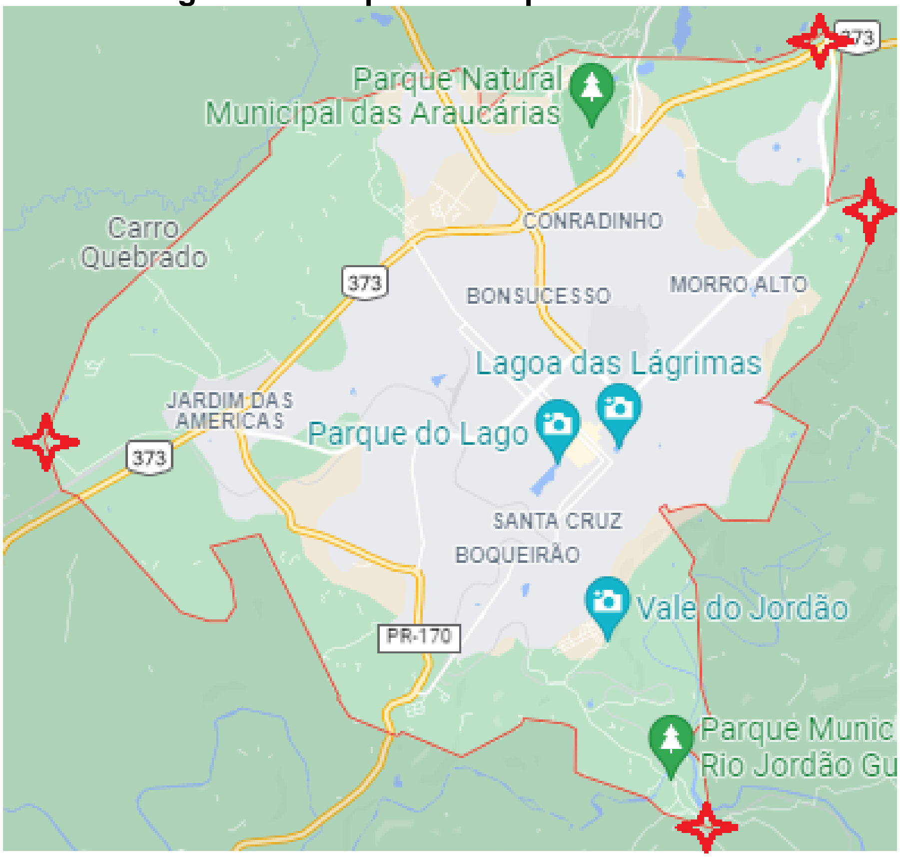
Thus, after knowing the technologies that will be used for the development of the dashboard, as well as its classification, the following Subsection 4.2 presents more details about DataCidade.

4.2 The DataCidade dashboard

In this Section, a simulation of how the DataCidade dashboard would behave is presented. The programming language used to develop it was Python, and the integrated development environment (IDE) used was Pycharm 2021.2.3. Finally, to deploy it online, the Streamlit webpage was used, as well as GitHub. Due to the inability to factually implement the project into a real city, the dashboard is made up of randomly generated data under pre-established boundaries.

The intent is to demonstrate how the collected data can visually be represented. The chosen city for this project is Guarapuava, located in the State of Paraná, and delimited in Figure 10.

Figure 10 - Map of Guarapuava - Paraná



Source: Google Maps (2022)

To randomly generate reports within the city's limits, the maximum longitude and latitude were taken from google maps in the north, south, east and west directions. The red stars represent those limits: South: -25.34153; North: -25.42497; West: -51.53191; East: -51.43131.

Then an Excel spreadsheet was used to generate random: GPS coordinates within these limits, Cadastro de Pessoa Física number (CPF), dates for each report ranging from 03/01/2020 to 01/01/2022, a number of likes that each report was given, and lastly, it was set as 75% of the reports being maintenance and 25% implementation.

It is well known that due to the shape of the city, some reports might be slightly out of the city limits. However, that does not compromise the project. A total of 100 reports were generated; in Figure 11, a sample of 10 of them is shown.

Figure 11 - Random reports sample

	ID	CPF	Date_day	Action	Lat	Lon	Num_Likes
0	1	6700395134	2021-04-12T00:00:00	Maintenance	-25.3543	-51.5000	21
1	2	7015882270	2021-11-28T00:00:00	Maintenance	-25.4063	-51.5091	88
2	3	6628971747	2021-12-09T00:00:00	Maintenance	-25.3608	-51.5149	46
3	4	7160021115	2021-03-17T00:00:00	Maintenance	-25.4004	-51.5206	82
4	5	6980934332	2021-05-20T00:00:00	Maintenance	-25.3983	-51.4514	41
5	6	6678500206	2020-12-01T00:00:00	Maintenance	-25.3999	-51.4771	30
6	7	6676102138	2020-05-21T00:00:00	Maintenance	-25.3963	-51.4650	35
7	8	6700970520	2021-12-07T00:00:00	Maintenance	-25.3490	-51.4967	21
8	9	6652173245	2020-12-02T00:00:00	Maintenance	-25.3585	-51.4704	48
9	10	6700395134	2021-12-15T00:00:00	Maintenance	-25.3430	-51.5085	74
10	11	7015882270	2021-10-23T00:00:00	Maintenance	-25.4229	-51.4516	14

Source: Elaborated by the author (2022)

The generation of these 100 reports allowed the development of other geographical tracking, such as cluster maps and heat maps. At the top of the dashboard is displayed a data overview with the postcode of the report as well as the reported age, which is the difference between the date to which it was created and the present day, as seen in Figure 12.

Figure 12 - Data overview

------------------Data Overview------------------

	ID	CPF	Date_day	Action	Lat	Lon	Num_Likes	postcode	Report_Age
0	1	6700395134	2021-04-12T00:00:00	Maintenance	-25.3543	-51.5000	21	85045-500	264
1	2	7015882270	2021-11-28T00:00:00	Maintenance	-25.4063	-51.5091	88	85031-141	34
2	3	6628971747	2021-12-09T00:00:00	Maintenance	-25.3608	-51.5149	46	85045-500	23
3	4	7160021115	2021-03-17T00:00:00	Maintenance	-25.4004	-51.5206	82	85031-141	290
4	5	6980934332	2021-05-20T00:00:00	Maintenance	-25.3983	-51.4514	41	85070180	226
5	6	6678500206	2020-12-01T00:00:00	Maintenance	-25.3999	-51.4771	30	85015-430	396
6	7	6676102138	2020-05-21T00:00:00	Maintenance	-25.3963	-51.4650	35	85010130	590
7	8	6700970520	2021-12-07T00:00:00	Maintenance	-25.3490	-51.4967	21	85045-500	25
8	9	6652173245	2020-12-02T00:00:00	Maintenance	-25.3585	-51.4704	48	85055-040	395
9	10	6700395134	2021-12-15T00:00:00	Maintenance	-25.3430	-51.5085	74	85045-500	17
10	11	7015882270	2021-10-23T00:00:00	Maintenance	-25.4229	-51.4516	14	85010-190	70

Source: Elaborated by the author (2022)

It is possible to scroll down and see all the information concerning each individual report. Figure 13 shows some descriptive statistics which can be further explored.

Figure 13 - Description of statistics

--------------Descriptive Statistics----

	atributes	max	min	media	mediana	std	variancia
0	Num_Likes	98	2	49.2100	45.5000	27.3453	747.7659
1	Report_Age	731	6	350.5900	374.0000	216.9407	47,063.2619

Source: Elaborated by the author (2022)

At this moment, the descriptive statistics encompass the number of likes of each report and its age, displaying the maximum and minimum values, the mean, the median, standard deviation and variation. In order to know which citizens have contributed the most, there is also a ranking and labelling chart to not only incentivize the engagement but also to make the project more friendly (this information will be provided to the citizens to foster engagement), as shown in Figure 14.

Figure 14 - Ranking and labeling

--------------Citizen Label---------

	Ranking	CPF	Num_Likes_Total	Label
0	1	6700395134	621	SUPERMAN | SUPERGIRL
1	2	6700970520	615	SUPERMAN | SUPERGIRL
2	3	7160021115	608	SUPERMAN | SUPERGIRL
3	4	6980934332	592	BATMAN | BATGIRL
4	5	7015882270	550	BATMAN | BATGIRL
5	6	6678500206	535	BATMAN | BATGIRL
6	7	6628971747	497	BATMAN | BATGIRL
7	8	6652173245	488	BATMAN | BATGIRL
8	9	6676102138	415	ROBIN

Source: Elaborated by the author (2022)

This ranking serves not only for engagement motivation but also, if it is in the best interest of the government, to possibly reward citizens that are contributing more.

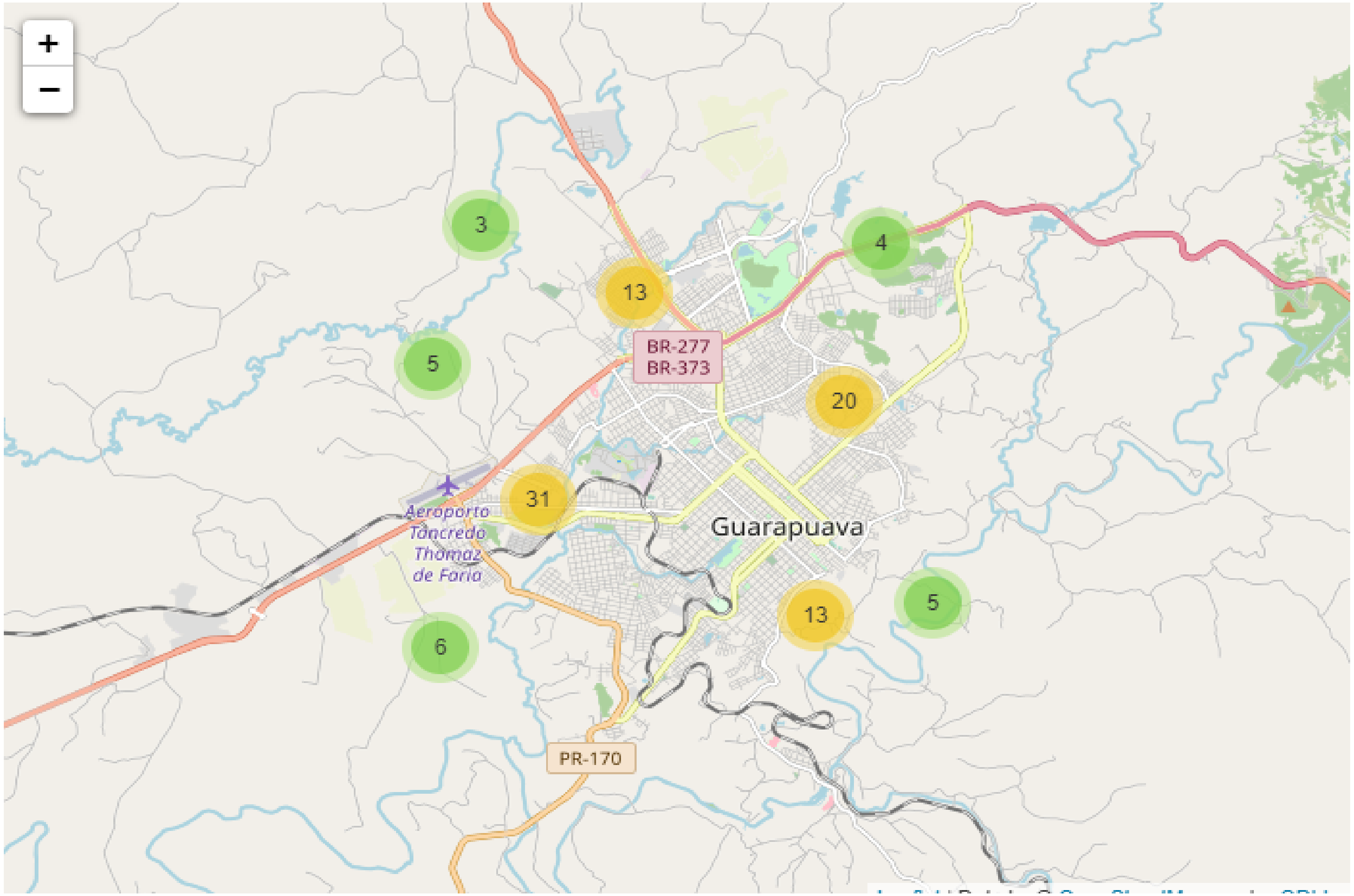
For the geolocation feature of the dashboard, the first map shows all 100 reports clustered in the city. As seen in Figure 15.

Figure 15 - 100 reports clustered

Source: Elaborated by the author (2022)

Next, in Figure 16, after clicking, it is possible to zoom in and visualize the 100 reports clustered into different regions.

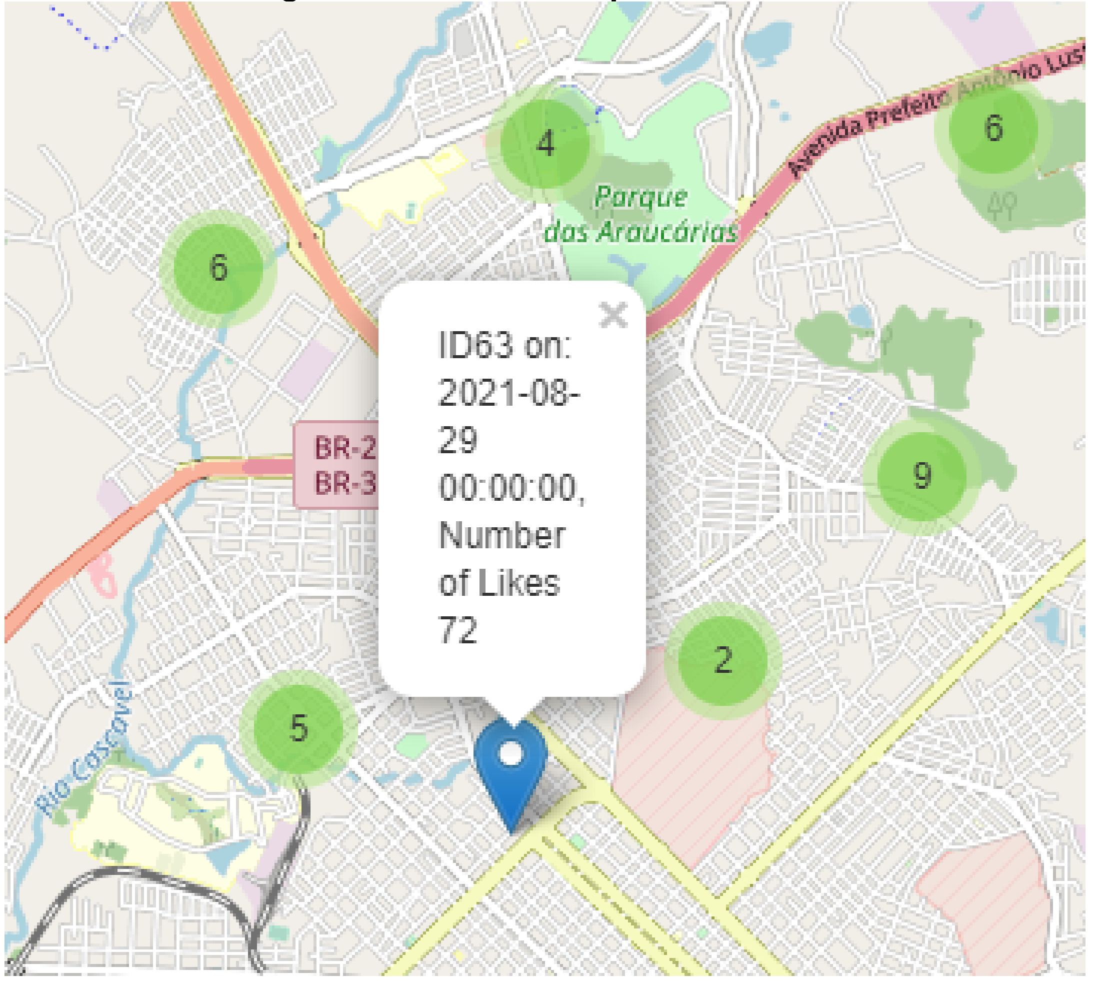
Figure 16 - 100 reports clustered into different regions



Source: Elaborated by the author (2022)

It is possible to further cluster by clicking and zooming, thus forming smaller groups. This feature is helpful for decision making when it comes to logistics for planning actions as well as understanding the areas that are most in need of aid. Reports can be zoomed until the individual report is found, and if clicked, the following information is displayed, as shown in Figure 17.

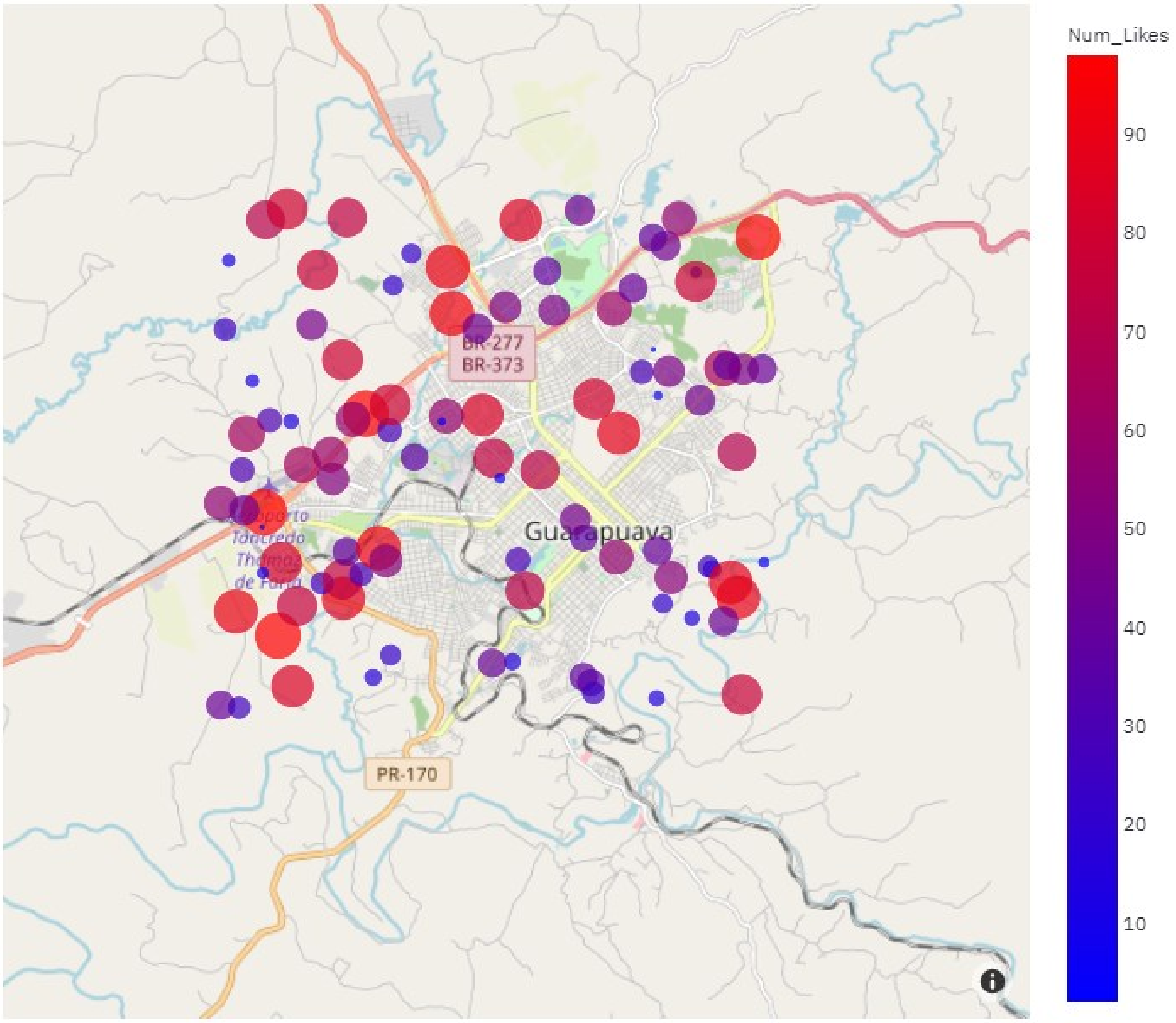
Figure 17 - Clustered report zoomed in



Source: Elaborated by the author (2022)

The information shown is the ID of the report, date and hour and a number of likes, as well as the visual information of the location. This information alone might be already useful, but further analysis enriches the project, such as in Figure 18.

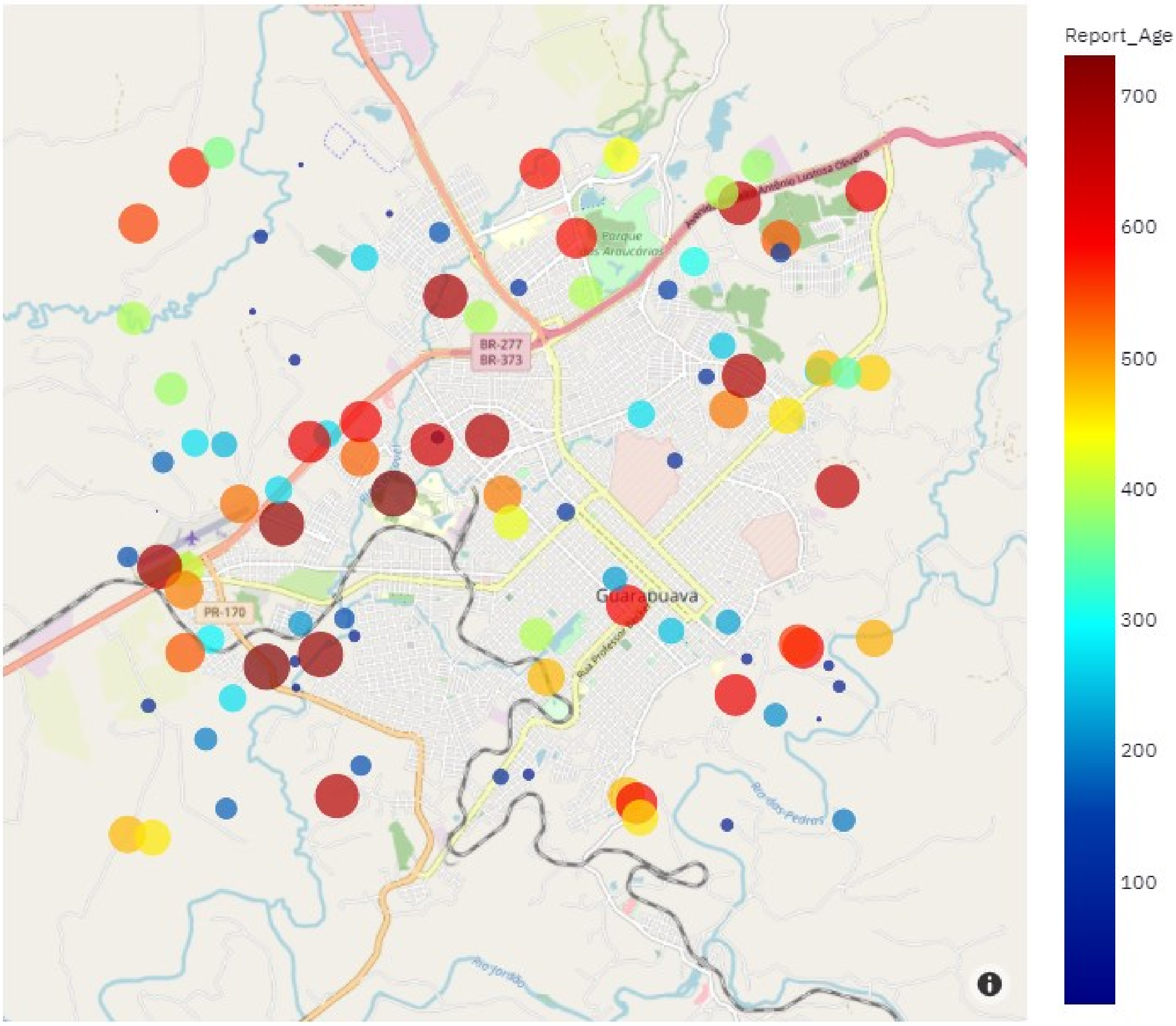
Figure 18 - Number of likes heat map



Source: Elaborated by the author (2022)

This heat map shows the most important reports. The number of likes is a way to assess the relevance of the report; the more likes it has, the more people it affects. It obeys the scale of colour on the right, ranging from blue (lowest) to red (highest), as well as a scale of size; the bigger, the higher the number of likes. This feature might be one of the most important ones as it measures the notoriety of the report as well the engagement. Next, an urgency map was created, as shown in Figure 19.

Figure 19 - Urgency map

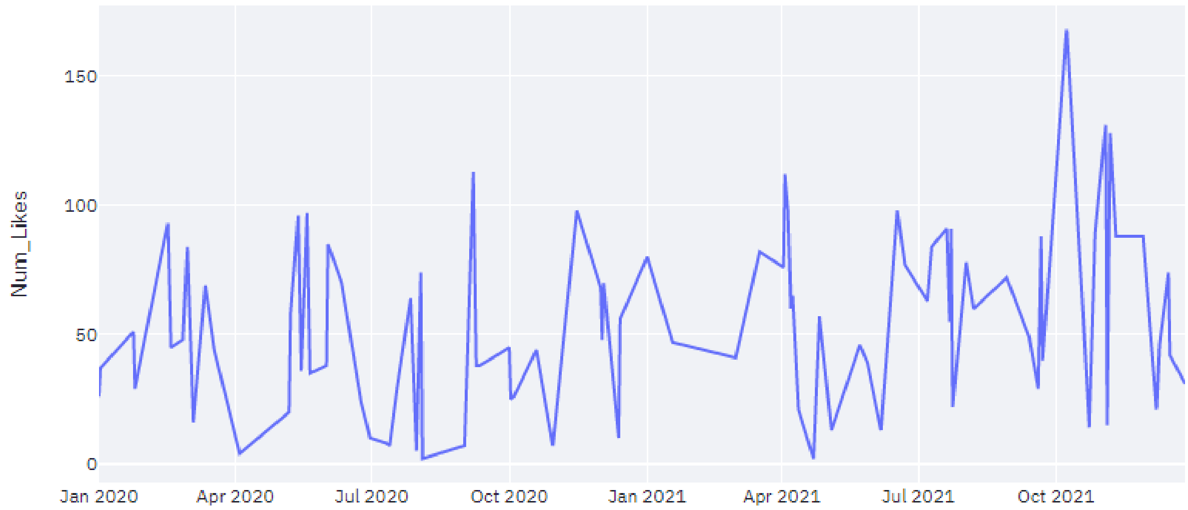


Source: Elaborated by the author (2022)

This map was created with the intention of highlighting the report's age. It is a way to bring attention to reports that might not have the same number of likes and engagement as others and are yet to be taken care of. The reports attend the scale on the right, blue being the youngest and red the oldest. The size of the reports also follows the age; the bigger, the older. These features have the intent to provide a visual diagnosis of the current situation.

In order to have an overall view of the engagement, the next feature is a chart that counts the number of likes through time, as seen in Figure 20.

Figure 20 - Interactivity through time



Source: Elaborated by the author (2022)

This chart displays the randomly generated data; therefore, due to the very nature of the data, it is not possible to infer any conclusions from this specific chart. However, if it was fed with real data, this would help understand the peaks and valleys of engagement and to understand their reason, whether they are holidays, seasonality or even just random factors. Lastly, a Gravity Urgency Tendency (GUT) matrix was constructed to rank the reports in order of importance, taking into account the gravity, urgency and tendency.

For the gravity parameter, the number of likes was considered by taking the range between the maximum and a minimum number of likes as a scale from 1 to 5. For the urgency parameter, the reported age was turned into a scale from 1 to 5, and due to the data being random and not realistic, the tendency was given a fixed number of 3. The results are shown in Figure 21.

Figure 21 - GUT matrix

	ID	Num_Likes	Report_Age	Gravity	Urgency	Tendency	GUT
18	19	98	412	5	5	3	75
43	44	93	685	5	5	3	75
58	59	85	578	5	5	3	75
59	60	84	672	5	5	3	75
68	69	96	598	5	5	3	75
92	93	80	365	5	5	3	75
20	21	64	523	4	5	3	60
21	22	70	569	4	5	3	60
31	32	72	481	4	5	3	60
44	45	74	516	4	5	3	60
45	46	69	660	4	5	3	60

Source: Elaborated by the author (2022)

The results named GUT in the table are the multiplication of the three chosen factors: gravity x urgency x tendency. As seen, ID numbers 19,44,59,60,69 and 93 were the top reports with a final score of 75. This feature is able to help prioritize the reports by giving the government a quick and direct starting point making it possible to establish an action plan beginning with the most important issues.

4.3 Discussions: DataCidade, Smart Cities domains and the SDGs

This Section aims to explain how the proposed tool in this study called DataCidade, aims to address all the Smart Cities pillars: Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environment and Smart Living. They will all be covered individually.

4.3.1 Smart economy

Crowdsensing in Smart Cities can be a powerful tool to foster feasibility. What is meant by that is that projects that tackle sound and air pollution monitoring, mobility and quality of life improvements, environmental solutions, and citizen engagement, among others, would not be possible had it been necessary to invest in hardware for sensing. Even though DataCidade doesn’t have a direct application to the economy; it was conceived seeking to fill the gap of not having financial conditions to implement smart solutions.

Bernas *et al*., (2018) analyzed the costs, dimensions, energy consumptions, and facility to install sensing technologies that focus on trafficking monitoring. It is possible to see in Figure 22 that a seemingly simple project such as vehicle and pedestrian detection can become expensive.

Figure 22 - Sensing technologies and their characteristics

Sensing Technology	Principle of Operation	Requirements			
		Cost	Small Dimensions	Energy Consumption	Easy to Install
Inductive loops	Inductance measurement	Low	No	High	No
Cameras	Image analysis	High	Yes	High	Yes
Magnetometers	Magnetic field measurement	Low	Yes	Low	Yes
Acoustic sensors	Acoustic pressure measurement	Medium	Yes	Low	Yes
Radars/LIDARs	Detection of reflected electromagnetic wave	High	No	High	Yes
Accelerometers	Vibration measurement	Medium	Yes	Low	Yes
Light sensors	Light intensity measurement	Low	Yes	Low	Yes
Passive infrared sensors	Infrared radiation measurement	Medium	Yes	Low	Yes
Ultrasonic sensors	Detection of reflected sound wave	Low	No	Medium	Yes
Wireless communication devices	Measurement of received signal strength	Low	Yes	Medium	Yes

Source: Bernas et al. (2018)

This is just an example of how expensive projects can become and, therefore, not feasible. Not only the costs can be a problem, but as seen in Figure x, other features have to be taken into accounts, such as the dimensionality of a device, energy consumption (more costs), and tech support. Crowdsensing, as proposed by DataCidade, will require the individual's / citizen's smartphone. As shown in Figure 6, the number of smartphone users in 2021 is projected to be 3.8 billion, and a smartphone is packed with useful sensors, as seen in Figure 23.

Figure 23 - Smartphone sensors

Source: Majumder et al. (2019)

This little device, which more than half of the world's population carries on a daily basis, is a very powerful sensing tool. Even though there are 13 sensors on a smartphone, DataCidade, as it is proposed in this study, needs only one: the GPS (global positioning system).

There are a plethora of things that can be done with these sensors. However, because DataCidade collects data provided by the user, meaning that is an active form of Crowdsensing.

The only information needed from the device is the GPS location. As for the information provided by the user, the main sensor is the person itself. Citizens will use their eyes, ears, and emotions to assess and report specific problems by inputting information on DataCidade tied with the geographic location provided by the GPS.

4.3.2 Smart people

There was a famous experiment done by Francis Galton in 1907 where he took an ox to a farmers' fair and invited the crowd of around 800 people to guess the exact weight of the animal; whoever guessed it correctly would win a prize. Even though nobody was able to precisely guess the weight of the ox (which was 544kg), the mean of all guesses was remarkably close to the correct answer. This became known as the wisdom of crowds (GALTON, 1907).

Perhaps the first to talk about such a phenomenon was Aristotle in his work Politics Book III:

For it is possible that the many, though not individually good men, yet when they come together may be better, not individually but collectively, than those who are so, just as public dinners to which many contribute are better than those supplied at one man's cost (ARISTOTLE, 1944)

This quote from Aristotle shows the importance of collective thinking and, most importantly, collective endeavors. Human beings are social beings, and cities are nothing but large human social settlements. Therefore, a Smart City must take advantage of Smart People.

As talked about in the book The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations (2004), by James Surowiecki, in order for a wise crowd to be formed, some requirements must be met:

1. Diversity of opinion
2. Independence of opinion
3. Decentralization for specialized and local knowledge
4. Aggregation - turning private opinion into collective decisions
5. Trust

All these requirements are met by people of a certain neighborhood. They have a diversity of opinions since they have different backgrounds and different life experiences, and they are as well independent of each other. Each person is able to contribute with their own specialized knowledge, seeking collective decision making, and as determined by law, all citizens are equal, therefore providing trust.

These are, after all, suppositions. There is no way to accurately confirm that all citizens meet those requirements. However, it's safe to state that the more educated the population, the higher the chances of having these requirements met.

4.3.3 Smart governance

For a City to be Smart, it is necessary to have a Smart Government behind it. Perhaps Figure 2 does not make justice to the importance of having a Smart Government, as all pillars might be supported by a Smart Governance. Just as in an orchestra, all instruments are essential for a beautiful piece of music to be played, but the conductor or the maestro (the government) is what keeps all instruments in tempo. Therefore, Smart Governance can be understood as being able to improve decision-making with the help of ICT, and the collaboration of citizens and stakeholders (PEREIRA *et al.*, 2018).

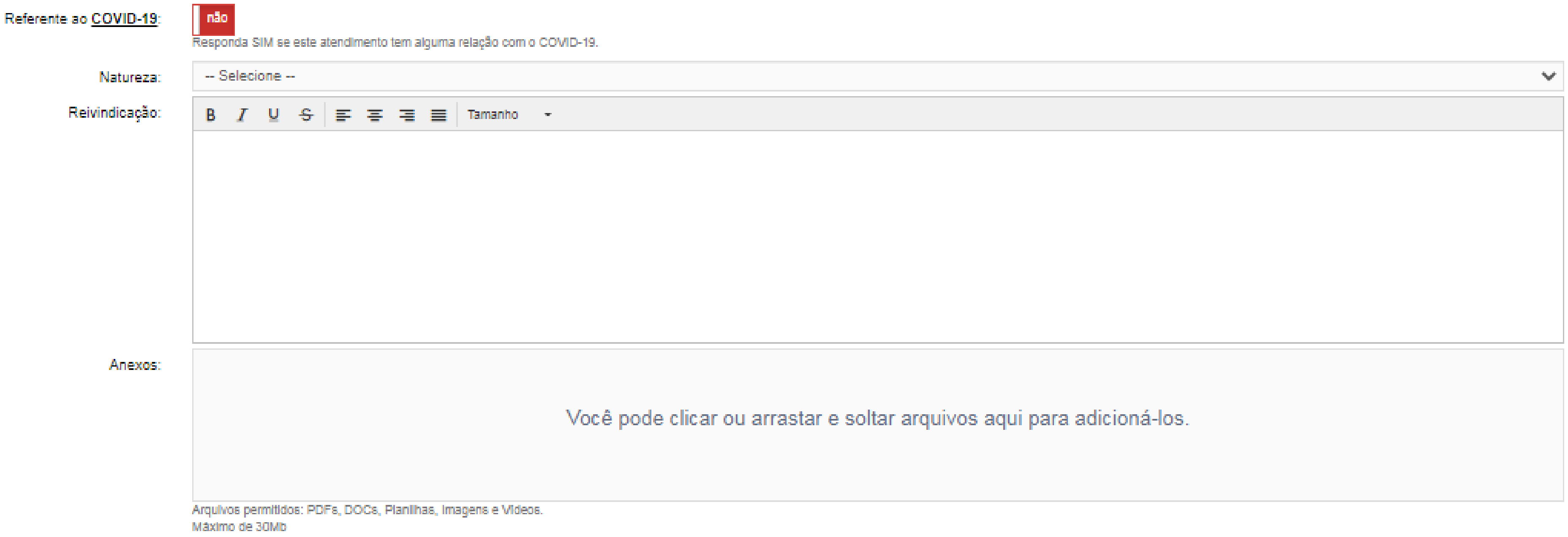
Taking as an example the city of Curitiba, capital of the State of Paraná, it has a web platform called Paraná Inteligencia Artificial (PIA), which is a type of Hearing Office or a city ombudsmen. This platform has a section where any citizen can make complaints, suggestions, or compliments concerning the city.

Figure 24 - PIA hearing system personal information section

Source: Sigo.pr.gov.br/cidadao (2021)

In this Section, the user has to insert all their personal information: name, e-mail, social security number, address, zip code, and phone number. There is a section at the bottom called vindication, where the citizen has to write a letter explaining what they wish to vindicate and choose the nature of the claim: information access law, compliment, suggestion, requirement, complaint, or report as seen in Figure 25.

Figure 25 - PIA hearing system report section



Source: Sigo.pr.gov.br/cidadao (2021)

Even though all this information is necessary to have an organized hearing system, every time the user wishes to engage, they have to input all the information again and write another letter.

Taking all this into account, citizens will probably be discouraged from engaging in such kinds of systems. A Smart Governance must be able to conduct collaboration as best as possible; citizens (engaging on DataCidade), government (using the information to improve decision-making), and stakeholders (DataCidade itself) must work together and in synchrony.

4.3.4 Smart mobility

Mobility is one of the main challenges for a Smart City, mainly because it is a convergence of factors such as people, environment, and economy Benevolo et al. (2016), also divide mobility into six most important objectives:

1. Pollution reduction;
2. Traffic jam reduction;
3. People's safety;
4. Noise pollution reduction;
5. Transfer speed improvement;
6. Transfer cost reduction

When it comes to mobility in Smart Cities, that's where most of the Crowdsensing articles focus; more than half of the papers in the portfolio of articles address this topic. Most articles tackle traffic congestion, parking, road condition, air pollution, noise pollution, and public transportation.

DataCidade, as it is designed, aims to address problems such as road conditions, traffic signs, accidents, public transportation, and traffic congestion. It aims to use the Crowdsensing technique to identify and monitor such problems by data collection through user input. This will be explained more, especially in Section 5.

4.3.5 Smart environment

When it comes to the environment, the papers in the portfolio of articles of this study address mainly noise pollution, vehicle pollution, and air pollution. Even though these are all extremely important to the environment, DataCidade plans to add a few more causes such as sanitation, green area monitoring in parks and squares, waste management, plagues, and pets. It is important to highlight that Crowdsensing initiatives such as vehicle sharing, traffic, and public transportation, even though considered to be Smart Mobility applications, also help cities environmentally (ALETÀ; ALONSO; RUIZ, 2017).

The GPS on DataCidade fixates the location of specific problems reported by the user; this architecture allows mapping wrongful waste management and the preservation status of green areas. It also allows pinpointing seasonal plagues such as raccoons, spiders, and scorpions (common occurrences in the State of Paraná, for example).

According to Vinod Kumar (2020), for a city to have a Smart Environment, it needs to make the environment itself smart; what is meant by that is that IoTs and ICTs tools are used for management practices, making the environment self-aware. This concept goes hand in hand with DataCidade, as the awareness (or sensing) will be raised by the people (crowd) that frequent the green areas of the city.

4.3.6 Smart living

According to Vinod Kumar (2020), Smart Living can encompass many different aspects ranging from religion to culture. However, the author cites 14 features of Smart Living that can serve as a compass for Smart Cities, as seen in Figure 26.

Chart 9 - Smart living features

N°	Feature
1	A smart city has strong and shared values.
2	A smart city records and celebrates local history, culture, and nature.
3	A smart city has a vibrant downtown, 24 h and 7 days a week
4	A smart city can provide the necessary safety and security to women, children, and senior citizens.
5	A smart city improves the urban way of life.
6	A smart city builds natural and cultural assets to build a good quality of life.
7	A smart city not only understands the big picture of urban liveability but also pays attention to small details.
8	A smart city has high-quality open and accessible public spaces.
9	A smart city has high-quality public services and amenities.
10	A smart city is an ideal place of living, especially for women, children, and senior citizens.
11	A smart city organizes festivals that celebrate people, life, and nature in the city
12	A smart city has a ritual event (or more) that symbolizes the values and spirations of the community.
13	A smart city celebrates and promotes art, cultural, and natural heritage in the city.
14	A smart city engages artists to improve and enrich the aesthetics of daily life of the city.

Source: Vinod Kumar (2020)

Out of the 14 features, DataCidade might be able to cover 7 of them. In terms of infrastructure, features 2,3,5,7,8,9 are addressed by the project as one of the goals of DataCidade is to preserve infrastructure as well as its maintenance and improvement. As for feature number 1, it would be a stretch to State that DataCidade covers it. However, it certainly has it in its peripheral vision to organically foster social cohesion through engagement, and participation and therefore creating a sense of belonging.

5 FINAL CONSIDERATIONS

This section will present the conclusions of the research, it will be divided into three subsections, the first will be the analysis of the objectives, the second part will present the general considerations, finally, the third part will present the limitations of the research and the suggestions for future works.

The research had the objective of proposing a crowdsensing tool for Smart Cities. The development of this work was supported by a systematic literature review conducted by the Methodi Ordinatio methodology. The applicability of crowdsourcing and crowdsensing techniques for Smart Cities and their benefits for SDGs were evaluated. Finally, a tool called DataCidade is presented.

5.1 Analysis of objectives

At the beginning of this study, a research problem was formulated that resulted in a questioning, which is opportune here, that some reflections are made about it. The question asked how to monitor problems in cities without high investment in infrastructure. To answer this question a main objective and four specific objectives were formulated. The main objective consisted in proposing a crowdsensing tool for Smart Cities which was only possible after the achievement of the other specific objectives.

The first specific objective “to survey the main Crowdsensing applications in Smart Cities” a literature review was conducted using the Methodi Ordinatio using as research keywords Smart Cities, crowdsourcing and crowdsensing. From this, a portfolio of articles was put together leading to the second specific objective “to analyze how these Crowdsensing applications support the six Smart Cities’ pillars”.

After a systematic reading was performed the main application of crowdsensing techniques were listed and found to be focusing on three main areas: People, Environment and Mobility. The third specific objective was “to structure a Crowdsensing tool to monitor major cities' problems regarding urban planning and maintenance”, for this, a tool called DataCidade was developed.

Finally, the fourth and last specific objective was “ to discuss how the project can support the Smart Cities pillars and the Sustainable Development Goals” which sought to validate the tool by the parameter of sustainability set by the UN; the main SDGs that matched the tool were listed and discussed.

5.2 General considerations

The main contributions of this study lie on the systematic literature review performed, the crowdsensing tool proposed and its benefits according to the UN's SDGs. Therefore, it is understood that the work is original the current literature, as there are no records of a crowdsensing tool applied to Smart Cities based on a systematic literature review that seeks to strengthen public management in order to foster the proposed sustainable development objectives by the UN.

5.3 Future works suggestions

During the development of this work, it was noticed the possibility of carrying out new studies that are outside the scope of the research carried out, but are of value for the deepening of the theme developed, namely:

- Big data analysis of the gathered data with the purpose of developing performance indicators of Smart Cities.
- The proposal of machine learning techniques to predict future problems and challenges of Smart Cities.
- To view the tool developed not only through the lenz of the SDGs but also by the universal declaration of human rights.

REFERENCES

ADAPA, S. Indian smart cities and cleaner production initiatives – Integrated framework and recommendations. **Journal of Cleaner Production**, *[S. l.]*, v. 172, p. 3351–3366, 2018.

AHVENNIEMI, H. *et al*. What are the differences between sustainable and smart cities? **Cities**, *[S. l.]*, v. 60, p. 234–245, 2017.

AKRAM, W.; VARALAKSHMI, M.; SUDEEPTHI, J. Streaming big data analytics-current status, challenges and connection of unbounded data processing platforms. **International Journal of Innovative Technology and Exploring Engineering (IJITEE)**, *[S. l.]*, v. 8, n. 9S2, p. 1–3, 2019.

ALBINO, V.; BERARDI, U.; DANGELICO, R. M. Smart Cities: Definitions, Dimensions, Performance, and Initiatives. **Journal of Urban Technology**, *[S. l.]*, v. 22, n. 1, p. 3–21, 2015.

ALETÀ, N. B.; ALONSO, C. M.; RUIZ, R. M. Arc. Smart Mobility and Smart Environment in the Spanish cities. **Transportation Research Procedia**, *[S. l.]*, v. 24, p. 163–170, 2017.

ALVEAR, O. *et al*. Crowdsensing in Smart Cities: Overview, Platforms, and Environment Sensing Issues. **Sensors 2018, Vol. 18, Page 460**, *[S. l.]*, v. 18, n. 2, p. 460, 2018.

ARISTOTLE. **Aristotle in 23 Volumes**, Vol. 21, translated by H. Rackham. Cambridge, MA, Harvard University Press; London, William Heinemann Ltd. 1944.

ATZORI, L.; IERA, A.; MORABITO, G. The Internet of Things: A survey. **Computer Networks**, *[S. l.]*, v. 54, n. 15, p. 2787–2805, 2010.

AUGER, A.; EXPOSITO, E.; LOCHIN, E. Towards the internet of everything: Deployment scenarios for a QoO-aware integration platform. **IEEE World Forum on Internet of Things, WF-IoT 2018 - Proceedings**, *[S. l.]*, v. 2018- January, p. 499–504, 2018.

BALACEANU, C.; TILEA, D. M.; PENU, D. EconPapers: Perspectives on Eco

Economics. Circular Economy and Smart Economy. **Academic Journal of Economic Studies**, *[S. l.]*, v. 3, n. 4, p. 105–109, 2017.

BATES, T. C.; GUPTA, S. Smart groups of smart people: Evidence for IQ as the origin of collective intelligence in the performance of human groups. **Intelligence**, *[S. l.]*, v. 60, p. 46–56, 2017.

BELLI, D. *et al*. A Probabilistic Model for the Deployment of Human-Enabled Edge Computing in Massive Sensing Scenarios. **IEEE Internet of Things Journal**, *[S. l.]*, v. 7, n. 3, p. 2421–2431, 2020.

BERNAS, M. *et al*. A Survey and Comparison of Low-Cost Sensing Technologies for Road Traffic Monitoring. **Sensors**, *[S. l.]*, v. 18, n. 10, p. 3243, 2018.

BOJANOVA, I.; HURLBURT, G.; VOAS, J. Imagineering an Internet of Anything. **Computer**, *[S. l.]*, v. 47, n. 6, p. 72–77, 2014.

BONNETT, M. Sustainable development, environmental education, and the significance of being in place. **The Curriculum Journal**, *[S. l.]*, v. 24, n. 2, p. 250–271, 2013.

BORGIA, E. The Internet of Things vision: Key features, applications and open issues. **Computer Communications**, *[S. l.]*, v. 54, p. 1–31, 2014.

BOUBICHE, D. *et al*. Mobile crowd sensing – Taxonomy, applications, challenges, and solutions. **Computers in Human Behavior**, *[S. l.]*, v. 101, p. 352–370, 2019.

CAMERO, A.; ALBA, E. Smart City and information technology: A review. **Cities**, *[S. l.]*, v. 93, p. 84–94, 2019.

CAPPONI, A. *et al*. A Survey on Mobile Crowdsensing Systems: Challenges, Solutions, and Opportunities. **IEEE Communications Surveys and Tutorials**, *[S. l.]*, v. 21, n. 3, p. 2419–2465, 2019.

CARAGLIU, A.; NIJKAMP, P. The impact of regional absorptive capacity on spatial knowledge spillovers: the Cohen and Levinthal model revisited. **Applied Economics** , *[S. l.]*, v. 44, n. 11, p. 1363–1374, 2011.

CARDONE, G. *et al*. Fostering participaction in smart cities: A geo-social crowdsensing platform. **IEEE Communications Magazine**, *[S. l.]*, v. 51, n. 6, p. 112–119, 2013.

CHAKERI, A.; JAIMES, L. G. An Incentive Mechanism for Crowdsensing Markets With Multiple Crowdsourcers. **IEEE Internet of Things Journal**, *[S. l.]*, v. 5, n. 2, p. 708–715, 2018.

CHARMONMAN, S.; MONGKHONVANIT, P. Special consideration for Big Data in IoE or Internet of Everything. *In*: International Conference On Ict And Knowledge Engineering 2015, Bangkok. **Anais** [...]. Bangkok: IEEE Computer Society, 2015. p. 147–150.

CHEN, X. *et al*. PAS: Prediction-Based Actuation System for City-Scale Ridesharing Vehicular Mobile Crowdsensing. **IEEE Internet of Things Journal**, *[S. l.]*, v. 7, n. 5, p. 3719–3734, 2020.

CHOURABI, H. *et al*. Understanding smart cities: An integrative framework. *In*: PROCEEDINGS OF THE ANNUAL HAWAII INTERNATIONAL CONFERENCE ON SYSTEM SCIENCES 2012, Maui. **Anais** [...]. Maui: IEEE Computer Society, 2012. p. 2289–2297.

CORSI, A. *et al*. Big data analytics as a tool for fighting pandemics: a systematic review of literature. **Journal of ambient intelligence and humanized computing**, *[S. l.]*, v. 12, n. 10, p. 9163–9180, 2020.

DASARI, V. *et al*. Game Theory in Mobile CrowdSensing: A Comprehensive Survey. **Sensors**, *[S. l.]*, v. 20, n. 7, p. 2055, 2020.

DI MARTINO, B. *et al*. **Internet of Everything, Algorithms, Methodologies, Technologies and Perspectives**. 1. ed. Singapore: Springer Singapore, 2018. v. 1.

ELMUSTAFA, S. A.; MUJTABA, E. Y. Internet of things in Smart Environment: Concept, Applications, Challenges, and Future Directions | Semantic Scholar. **Computer Science, Environmental Science**, *[S. l.]*, v. 1, n. 1, 2019.

ENYOGHASI, C.; BADURDEEN, F. Industry 4.0 for sustainable manufacturing: Opportunities at the product, process, and system levels. **Resources, Conservation and Recycling**, *[S. l.]*, v. 166, p. 105362, 2021.

EVANS, D. **The Internet of Everything: How More Relevant and Valuable Connections Will Change the World.** Cisco Internet Business Solutions Group (IBSG), Cisco Systems, Inc., San Jose, 1-9, 2012.

FARKAS, K. *et al*. Crowdsending based public transport information service in smart cities. **IEEE Communications Magazine**, *[S. l.]*, v. 53, n. 8, p. 158–165, 2015.

FIANDRINO, C. *et al*. CrowdSenSim: A simulation platform for mobile crowdsensing in realistic urban environments. **IEEE Access**, *[S. l.]*, v. 5, p. 3490–3503, 2017.

FOSCHINI, Luca *et al*. Edge-enabled Mobile Crowdsensing to Support Effective Rewarding for Data Collection in Pandemic Events. **Journal of Grid Computing 2021 19:3**, *[S. l.]*, v. 19, n. 3, p. 1–17, 2021.

FULMAN, N.; BENENSON, I. Simulating parking for establishing parking prices. **Procedia Computer Science**, *[S. l.]*, v. 109, p. 911–916, 2017.

GALTON, F. Vox populi. **Nature**, *[S. l.]*, v. 75, n. 1949, p. 450–451, 1907.

GANESAN, E. *et al*. SDN-Enabled FiWi-IoT Smart Environment Network Traffic Classification Using Supervised ML Models. **Photonics**, *[S. l.]*, v. 8, n. 6, p. 201, 2021.

GANTI, R. K.; YE, F.; LEI, H. Mobile crowdsensing: Current state and future challenges. **IEEE Communications Magazine**, *[S. l.]*, v. 49, n. 11, p. 32–39, 2011.

GRANIER, B.; KUDO, H. How are citizens involved in smart cities? **Analysing citizen participation in Japanese ``Smart Communities"**. Information Polity. 21. 61-76, 2016.

GERLA, M. *et al*. Internet of vehicles: From intelligent grid to autonomous cars and vehicular clouds. *In*: IEEE WORLD FORUM ON INTERNET OF THINGS, WF-IOT 2014, Seoul. **Anais** [...]. Seoul: IEEE Computer Society, 2014. p. 241–246.

GIL, A. C. **Métodos e Técnicas de Pesquisa Social**. 6. ed. [s.l.] : 6, 2008. b. v. 1

GISDAKIS, S.; GIANNETSOS, T.; PAPADIMITRATOS, P. SPPEAR: Security & privacy-preserving architecture for participatory-sensing applications. **WiSec 2014 -**

Proceedings of the 7th ACM Conference on Security and Privacy in Wireless and Mobile Networks, *[S. l.]*, v. 1, n. 1, p. 39–50, 2014.

GIULIODORI, A.; BERRONE, P.; RICART, J. E. Where smart meets sustainability: The role of Smart Governance in achieving the Sustainable Development Goals in cities: **BRQ Business Research Quarterly**, *[S. l.]*, p. 234094442210912, 2022.

GLOBAL, IGI. **What is Smart Economy**. 2022. Disponível em: https://www.igi-global.com/dictionary/smart-city--smart-citizen--smart-economy/87778. Acesso em: 2 jun. 2022.

GOOGLE INC. **Google Science Journal**, 2016. Disponível em: https://makingscience.withgoogle.com/science-journal/. Acesso em: 3 mai. 2022.

GODOY, A. S. Pesquisa qualitativa: tipos fundamentais. **Revista de Administração de Empresas**, *[S. l.]*, v. 35, n. 3, p. 20–29, 1995.

GRAY, S.; O'BRIEN, O.; HÜGEL, S. Collecting and visualizing real-time urban data through city dashboards. **Built Environment**, *[S. l.]*, v. 42, n. 3, p. 498–509, 2016.

GUO, B. *et al*. Mobile crowd sensing and computing: When participatory sensing meets participatory social media. **IEEE Communications Magazine**, *[S. l.]*, v. 54, n. 2, p. 131–137, 2016.

GUO, B. *et al*. Mobile Crowd Sensing and Computing. **ACM Computing Surveys (CSUR)**, *[S. l.]*, v. 48, n. 1, p. 1–31, 2015.

GUO, B. *et al*. From participatory sensing to Mobile Crowd Sensing. *In*: IEEE International Conference On Pervasive Computing And Communication Workshops 2014, **Anais** [...]. : IEEE Computer Society, 2014. p. 593–598.

GUPTA, A. *et al*. MClerk: Enabling mobile crowdsourcing in developing regions. *In*: CONFERENCE ON HUMAN FACTORS IN COMPUTING SYSTEMS - PROCEEDINGS 2012, **Anais** [...]. [s.l: s.n.] p. 1843–1852.

HÄHNEL, D. *et al*. Mapping and localization with RFID technology. *In*: IEEE International Conference On Robotics And Automation 2004, **Anais** [...]. : Institute of Electrical and Electronics Engineers Inc., 2004. p. 1015–1020..

HANCKE, G. P.; DE SILVA, B. C.; HANCKE, G. P. The Role of Advanced Sensing in Smart Cities. **Sensors**, *[S. l.]*, v. 13, n. 1, p. 393–425, 2012.

HEATON, J.; PARLIKAD, A. K. A conceptual framework for the alignment of infrastructure assets to citizen requirements within a Smart Cities framework. **Cities**, *[S. l.]*, v. 90, p. 32–41, 2019.

HÎRŢAN, L. A.; DOBRE, C.; GONZÁLEZ-VÉLEZ, H. Blockchain-based Reputation for Intelligent Transportation Systems. **Sensors 2020, Vol. 20, Page 791**, *[S. l.]*, v. 20, n. 3, p. 791, 2020.

HOFBAUER, J.; SIGMUND, K. Evolutionary game dynamics. **Bulletin of the American Mathematical Society**, *[S. l.]*, v. 40, n. 4, p. 479–519, 2003.

JEZDOVIĆ, I. *et al*. A crowdsensing platform for real-time monitoring and analysis of noise pollution in smart cities. **Sustainable Computing: Informatics and Systems**, *[S. l.]*, v. 31, p. 100588, 2021.

KARGER, E.; JAGALS, M.; AHLEMANN, F. Blockchain for Smart Mobility: Literature Review and Future Research Agenda. **Sustainability**, *[S. l.]*, v. 13, n. 23, p. 13268, 2021. DOI: 10.3390/SU132313268.

KIM, K.; JUNG, J. K.; CHOI, J. Y. Impact of the Smart City Industry on the Korean National Economy: Input-Output Analysis. **Sustainability**, *[S. l.]*, v. 8, n. 7, p. 649, 2016.

KOURTIT, K.; NIJKAMP, P. Big data dashboards as smart decision support tools for i-cities – An experiment on stockholm. **Land Use Policy**, *[S. l.]*, v. 71, p. 24–35, 2018.

KUMMITHA, R. K. R.; CRUTZEN, N. How do we understand smart cities? An evolutionary perspective. **Cities**, *[S. l.]*, v. 67, p. 43–52, 2017.

LEE, J. S.; HOH, B. Sell your experiences: A market mechanism based incentive for participatory sensing. *In*: IEEE International Conference On Pervasive Computing And Communications, PERCOM 2010, **Anais** [...]. : IEEE Computer Society, 2010. p. 60–68.

LI, X. *et al*. Towards sustainable smart cities: An empirical comparative assessment and development pattern optimization in China. **Journal of Cleaner Production**, *[S. l.]*, v. 215, p. 730–743, 2019.

LIU, Y.; KONG, L.; CHEN, G. Data-Oriented Mobile Crowdsensing: A Comprehensive Survey. **IEEE Communications Surveys and Tutorials**, *[S. l.]*, v. 21, n. 3, p. 2849–2885, 2019.

MAJUMDER, S.; DEEN, M. J. Smartphone Sensors for Health Monitoring and Diagnosis. **Sensors**, *[S. l.]*, v. 19, n. 9, p. 2164, 2019.

MONTORI, F.; BEDOGNI, L.; BONONI, L. A Collaborative Internet of Things Architecture for Smart Cities and Environmental Monitoring. **IEEE Internet of Things Journal**, *[S. l.]*, v. 5, n. 2, p. 592–605, 2018.

NAM, T.; PARDO, T. A. Conceptualizing smart city with dimensions of technology, people, and institutions. **ACM International Conference Proceeding Series**, *[S. l.]*, v. 1, n. 1, p. 282–291, 2011.

NAPHADE, M. *et al*. Smarter cities and their innovation challenges. **Computer**, *[S. l.]*, v. 44, n. 6, p. 32–39, 2011. DOI: 10.1109/MC.2011.187.

NIKKI HAN, M. J.; KIM, M. J. A critical review of the smart city in relation to citizen adoption towards sustainable smart living. **Habitat International**, *[S. l.]*, v. 108, p. 102312, 2021.

OGIE, R. I. Adopting incentive mechanisms for large-scale participation in mobile crowdsensing: from literature review to a conceptual framework. **Human-centric Computing and Information Sciences**, *[S. l.]*, v. 6, n. 1, p. 1–31, 2016.

WORLD POPULATION GROWTH, **ourworldindata**, May 2019. Disponível em <https://ourworldindata.org/world-population-growth> Acesso 16, ago. de 2020.

PAGANI, R. *et al*. On Smart Cities and Sustainable Development Goals. *In*: Congresso Latino Ibero- Americana De Gestão De Tecnologia (ALTEC) 2019, Medellín. **Anais** [...]. Medellín p. 18. Disponível em: https://www.researchgate.net/publication/341295126_On_Smart_Cities_and_Sustainable_Development_Goals. Acesso em: 2 jun. 2022.

PAGANI, R. N.; KOVALESKI, J. L.; DE RESENDE, L. M. M. TICs na composição da Methodi Ordinatio: construção de portfólio bibliográfico sobre Modelos de Transferência de Tecnologia. **Ciência da Informação**, *[S. l.]*, v. 24, n. 2, p. 161–187, 2018.

PAGANI, R. N.; KOVALESKI, J. L.; DE RESENDE, L. M. M. Methodi Ordinatio: a proposed methodology to select and rank relevant scientific papers encompassing the impact factor, number of citation, and year of publication. **Scientometrics**, *[S. l.]*, v. 105, n. 3, p. 2109–2135, 2015.

PAIVA, S. *et al*. Enabling Technologies for Urban Smart Mobility: Recent Trends, Opportunities and Challenges. **Sensors**, *[S. l.]*, v. 21, n. 6, p. 2143, 2021.

PEREIRA, G. *et al*. Smart governance in the context of smart cities: A literature review. **Information Polity**, *[S. l.]*, v. 23, n. 2, p. 143–162, 2018.

POPOVA, Y. Economic or financial substantiation for smart city solutions: a literature study. **Інститут трансформації суспільства**, *[S. l.]*, v. 183, n. 5–6, p. 125–133, 2020.

POURNARAS, E.; YADHUNATHAN, S.; DIACONESCU, A. Holarchic structures for decentralized deep learning: a performance analysis. **Cluster Computing**, *[S. l.]*, v. 23, n. 1, p. 219–240, 2020.

POURYAZDAN, M.; KANTARCI, B. The Smart Citizen Factor in Trustworthy Smart City Crowdsensing. **IT Professional**, *[S. l.]*, v. 18, n. 4, p. 26–33, 2016.

POURYAZDAN, M. *et al*. Quantifying user reputation scores, data trustworthiness, and user incentives in mobile crowd-sensing. **IEEE Access**, *[S. l.]*, v. 5, p. 1382–1397, 2017.

QADER, W. A.; AMEEN, M. M.; AHMED, B. I. Big Data Characteristics, Architecture, Technologies and Applications. **Journal of Computer Science**, *[S. l.]*, v. 16, n. 6, p. 817–824, 2020. DOI: 10.3844/JCSSP.2020.817.824.

GURASHI, R. The era of the smart people. How techno capitalism is changing the lifestyles of the individuals of the smart society. **Periodico telematico di Storia e Scienze Umane**, *[S. l.]*, v. 1, n. 86, p. 1–12, 2018.

RACO, M. Securing Sustainable Communities: Citizenship, Safety and Sustainability in the New Urban Planning. **European Urban and Regional Studies**, *[S. l.]*, v. 14, n. 4, p. 305–320, 2016.

RAMÍREZ-MORENO, Mauricio A. *et al*. Sensors for Sustainable Smart Cities: A Review. **Applied Sciences**, *[S. l.]*, v. 11, n. 17, p. 8198, 2021.

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 Studies**, *[S. l.]*, v. 81, p. 31–48, 2015.

SÁNCHEZ-CORCUERA, R. *et al*. Smart cities survey: Technologies, application domains and challenges for the cities of the future: **International Journal of Distributed Sensor Networks**, *[S. l.]*, v. 15, n. 6, 2019.

SARIKAYA, A. *et al*. What do we talk about when we talk about dashboards? **IEEE Transactions on Visualization and Computer Graphics**, *[S. l.]*, v. 25, n. 1, p. 682–692, 2019.

SHAFIQUE, M. *et al*. Effect of IoT Capabilities and Energy Consumption behavior on Green Supply Chain Integration. **Applied Sciences**, *[S. l.]*, v. 8, n. 12, p. 2481, 2018.

SHAHROUR, I.; XIE, X. Role of Internet of Things (IoT) and Crowdsourcing in Smart City Projects. **Smart Cities**, *[S. l.]*, v. 4, n. 4, p. 1276–1292, 2021.

SILVA, M. *et al*. A Crowdsensing Platform for Monitoring of Vehicular Emissions: A Smart City Perspective. **Future Internet**, *[S. l.]*, v. 11, n. 1, p. 13, 2019.

SILVA, E. L.; MENEZES, E. M. Methodology of the research and elaboration of dissertation. Florianópolis: UFSC, 2005.

SINGH, G.; BANSAL, D.; SOFAT, S. A smartphone based technique to monitor driving behavior using DTW and crowdsensing. **Pervasive and Mobile Computing**, *[S. l.]*, v. 40, p. 56–70, 2017.

SRINIVAS, K.; JABBAR, M. A.; NEERAJA, K. S. Sensors in IoE: A Review. **International Journal of Engineering & Technology**, *[S. l.]*, v. 7, n. 4.6, p. 158–160, 2018.

STALETIĆ, N. *et al*. Citizens' readiness to crowdsource smart city services: A developing country perspective. **Cities**, *[S. l.]*, v. 107, p. 102883, 2020.

STANKOVIC, J. A. Research directions for the internet of things. **IEEE Internet of Things Journal**, *[S. l.]*, v. 1, n. 1, p. 3–9, 2014.

SUCASAS, V. *et al*. A Signature Scheme with Unlinkable-yet-Accountable Pseudonymity for Privacy-Preserving Crowdsensing. **IEEE Transactions on Mobile Computing**, *[S. l.]*, v. 19, n. 4, p. 752–768, 2020.

SUN, Y. *et al*. Internet of Things and Big Data Analytics for Smart and Connected Communities. **IEEE Access**, *[S. l.]*, v. 4, p. 766–773, 2016.

SUROWIECKI, J. **The Wisdom of Crowds**. 1. ed. [s.l.] : Anchor, 2004. v. 1 Disponível em: https://www.amazon.com.br/dp/B000FCKC3I/ref=dp-kindle-redirect?_encoding=UTF8&btkr=1. Acesso em: 2 jun. 2022.

SWAPAN, M. S. H. Who participates and who doesn't? Adapting community participation model for developing countries. **Cities**, *[S. l.]*, v. 53, p. 70–77, 2016.

TALASILA, M.; CURTMOLA, R.; BORCEA, C. Improving location reliability in crowd sensed data with minimal efforts. *In*: Proceedings Of 2013 6th Joint Ifip Wireless And Mobile Networking Conference, WMNC 2013 2013, **Anais** [...]. [s.l: s.n.]

TALASILA, M.; CURTMOLA, R.; BORCEA, C. Mobile Crowd Sensing. **Handbook of Sensor Networking: Advanced Technologies and Applications**, *[S. l.]*, p. 1–12, 2015.

TUREČKOVÁ, K.; NEVIMA, J. The Cost Benefit Analysis for the Concept of a Smart City: How to Measure the Efficiency of Smart Solutions? **Sustainability**, *[S. l.]*, v. 12, n. 7, p. 2663, 2020.

UN. **Sustainable Development Goals**, 2015. Disponível em: https://www.un.org/sustainabledevelopment/. Acesso em: 15 Jan. 2019.

UN. Development Programme. **Piecing together resilient cities | by UN Development Programme | Medium**. 2022. Disponível em: https://undp.medium.com/piecing-together-resilient-cities-173b9e0e75c4. Acesso em: 2 jun. 2022.

UNESCO. **From green economies to green societies: UNESCO's commitment to sustainable development**, 2011. Disponível em: http://unesdoc.unesco.org/images/0021/002133/213311e.pdf. Acesso em: 06 Jun. 2022.

VINOD KUMAR, T. M. **Smart environment for smart cities**. 1. ed. [s.l.] : Springer, 2020. v. 1

WANG, X. *et al*. A City-Wide Real-Time Traffic Management System: Enabling Crowdsensing in Social Internet of Vehicles. **IEEE Communications Magazine**, *[S. l.]*, v. 56, n. 9, p. 19–25, 2018.

WAZE. **About us**, 2022. Disponível em: https://www.waze.com/en/waze. Acesso em 06 Jun. 2022.

WEXLER, S.; SHAFFER, J.; COTGREAVE, A. **The Big Book of Dashboards**: Visualizing Your Data Using Real-World Business Scenarios. 1. ed. Nova Jersey: John Wiley & Sons, 2017.

WCED. **Our common future. Oxford**: Oxford University Press, 1987.

XU, G. *et al*. Internet of Things in Marine Environment Monitoring: A Review. **Sensors**, *[S. l.]*, v. 19, n. 7, p. 1711, 2019.

YANG, D. *et al*. Incentive Mechanisms for Crowdsensing: Crowdsourcing with Smartphones. **IEEE/ACM Transactions on Networking**, *[S. l.]*, v. 24, n. 3, p. 1732–1744, 2016.

YIN, B. *et al*. An Efficient Collaboration and Incentive Mechanism for Internet of Vehicles (IoV) with Secured Information Exchange Based on Blockchains. **IEEE Internet of Things Journal**, *[S. l.]*, v. 7, n. 3, p. 1582–1593, 2020.

YU, J. *et al*. A Framework on Semantic Thing Retrieval Method in IoT and IoE

Environment. *In*: 2018 International Conference On Platform Technology And Service, Platcon 2018 2018, **Anais** [...]. : Institute of Electrical and Electronics Engineers Inc., 2018.

ZENG, B. *et al*. BRAKE: Bilateral Privacy-Preserving and Accurate Task Assignment in Fog-Assisted Mobile Crowdsensing. **IEEE Systems Journal**, *[S. l.]*, v. 15, n. 3, p. 4480–4491, 2020.

ZHANG, A. *et al*. Blockchain-based life cycle assessment: An implementation framework and system architecture. **Resources, Conservation and Recycling**, *[S. l.]*, v. 152, p. 104512, 2020.

ZHU, K.; ZHANG, A.; NIYATO, D. Cost-Effective Active Sparse Urban Sensing: Adversarial Autoencoder Approach. **IEEE Internet of Things Journal**, *[S. l.]*, v. 8, n. 15, p. 12064–12078, 2021.

ZHU, W. *et al*. Multitask Allocation to Heterogeneous Participants in Mobile Crowd Sensing. **Wireless Communications and Mobile Computing**, *[S. l.]*, v. 2018, 2018.

ZOU, J. *et al*. Integrated Blockchain and Cloud Computing Systems: A Systematic Survey, Solutions, and Challenges. **ACM Computing Surveys (CSUR)**, *[S. l.]*, v. 54, n. 8, 2021.

APPENDIX A – Portfolio of articles

Chart 10 - Portfolio of articles

Article	InOrdinatio
Internet of Things and Big Data Analytics for Smart and Connected Communities	800
Fostering ParticipAction in Smart Cities: A Geo-Social Crowdsensing Platform	376
A Collaborative Internet of Things Architecture for Smart Cities and Environmental Monitoring	266
Urban computing in the wild: A survey on large scale participation and citizen engagement with ubiquitous computing, cyber physical systems, and Internet of Things	181
Quantifying User Reputation Scores, Data Trustworthiness, and User Incentives in Mobile Crowd-Sensing	181
PortoLivingLab: An IoT-Based Sensing Platform for Smart Cities	172
Anchor-Assisted and Vote-Based Trustworthiness Assurance in Smart City Crowdsensing	166
Multidimensional Context-Aware Social Network Architecture for Mobile Crowdsensing	162
Crowdsensing in Smart Cities: Overview, Platforms, and Environment Sensing Issues	160
Federated Learning for Internet of Things: A Comprehensive Survey	144
An Efficient Collaboration and Incentive Mechanism for Internet of Vehicles (IoV) With Secured Information Exchange Based on Blockchains	133
CrowdSenSim: a Simulation Platform for Mobile Crowdsensing in Realistic Urban Environments	132
Towards a Practical Crowdsensing System for Road Surface Conditions Monitoring	125
DREAM: Online Control Mechanisms for Data Aggregation Error Minimization in Privacy-Preserving Crowdsensing	124
Blockchain-based Reputation for Intelligent Transportation Systems	123
Crowdsending Based Public Transport Information Service in Smart Cities	121
An intelligent big data collection technology based on micro mobile data centers for crowdsensing vehicular sensor network	115
A Survey on Device Behavior Fingerprinting: Data Sources, Techniques, Application Scenarios, and Datasets	112
Adopting incentive mechanisms for large-scale participation in mobile crowdsensing: from literature review to a conceptual framework	107
Game Theory in Mobile CrowdSensing: A Comprehensive Survey	104
A Shared Bus Profiling Scheme for Smart Cities Based on Heterogeneous Mobile Crowdsourced Data	103
Citizens' readiness to crowdsource smart city services: A developing country perspective	103
Privacy-Preserving Online Task Allocation in Edge-Computing-Enabled Massive Crowdsensing	101
Shared micromobility-driven modal identification of urban bridges	101
Enabling Green Crowdsourced Social Delivery Networks in Urban Communities	100
A blockchain-based creditable and distributed incentive mechanism for participant mobile crowdsensing in edge computing	100
PRVB: Achieving Privacy-Preserving and Reliable Vehicular Crowdsensing via Blockchain Oracle	98
A smartphone based technique to monitor driving behavior using DTW and crowdsensing	98
On the Need of Trustworthy Sensing and Crowdsourcing for Urban Accessibility in Smart City	98
Internet of Things for Noise Mapping in Smart Cities: State of the Art and Future Directions	97
Article (continuation)	**InOrdinatio**

The Smart Citizen Factor in Trustworthy Smart City Crowdsensing	97
PRICE: Privacy and Reliability-Aware Real-Time Incentive System for Crowdsensing	96
A crowdsensing platform for real-time monitoring and analysis of noise pollution in smart cities	96
Sociability-Driven Framework for Data Acquisition in Mobile Crowdsensing Over Fog Computing Platforms for Smart Cities	95
A Crowdsensing Platform for Monitoring of Vehicular Emissions: A Smart City Perspective	95
BRAKE: Bilateral Privacy-Preserving and Accurate Task Assignment in Fog-Assisted Mobile Crowdsensing	95
PAS: Prediction-Based Actuation System for City-Scale Ridesharing Vehicular Mobile Crowdsensing	94
Timeliness-Aware Incentive Mechanism for Vehicular Crowdsourcing in Smart Cities	94
Role of Internet of Things (IoT) and Crowdsourcing in Smart City Projects	94
Cost-Effective Active Sparse Urban Sensing: Adversarial Autoencoder Approach	93
BiCrowd: Online Biobjective Incentive Mechanism for Mobile Crowdsensing	93
A Signature Scheme with Unlinkable-yet-Accountable Pseudonymity for Privacy-Preserving Crowdsensing	93
A Student Attendance Management Method Based on Crowdsensing in Classroom Environment	93
Blockchain-Based Model for Nondeterministic Crowdsensing Strategy With Vehicular Team Cooperation	92
Frequency Identification of Bridges Using Smartphones on Vehicles with Variable Features	92
A Probabilistic Model for the Deployment of Human-Enabled Edge Computing in Massive Sensing Scenarios	91
Edge-enabled Mobile Crowdsensing to Support Effective Rewarding for Data Collection in Pandemic Events	91
Multi-Blockchain Structure for a Crowdsensing-Based Smart Parking System	88
Efficient Time-Stable Geocast Routing in Delay-Tolerant Vehicular Ad-Hoc Networks	86
Towards smart cities: crowdsensing-based monitoring of transportation infrastructure using in-traffic vehicles	86
An Incentive Mechanism for Crowdsensing Markets With Multiple Crowdsourcers	85
Task allocation for crowdsensing based on submodular optimization	82
Quality Estimation for Scarce Scenarios Within Mobile Crowdsensing Systems	81
Innovative Approaches for Noise Management in Smart Cities: a Review	81
A Mobile Crowd Sensing Framework for Suspect Investigation: An Objectivity Analysis and De-Identification Approach	81
Mobile Crowd Sensing RPL-based routing protocol for smart city	80

Source: Elaborated by the author (2022)

ANNEX A - Areas and subareas of Productions Engineering

Chart 11 – Areas and subareas of production engineering

Area	Sub-area
1. PRODUCTION MANAGEMENT	1.1. Production Systems Management 1.2. Planning and production control 1.3. Supply Chain Logistics and Management 1.3.1. Physical arrangement of Machines, Equipment and Facilities 1.3.2. Material handling 1.4. Factory and Industrial Installations Project 1.5. Maintenance management 1.6. Production Simulation 1.7. Productive Process Management 1.7.1. Discrete Productive Process Management 1.7.2. Management of Continuous Productive Processes 1.7.3. Automation Management of Equipment and Processes 1.7.4. Productive Process Planning
2. QUALITY MANAGEMENT	2.1. Statistical Quality Control 2.2. Standardization and Certification for Quality 2.3. Metrological Quality Organization 2.4. Reliability of Equipment, Machines and Products 2.5. Quality in Services
3. ECONOMIC MANAGEMENT	3.1. Economic engineering 3.2. Costs management 3.3. Project Financial Management 3.4. Investment Management
4. ERGONOMICS AND WORK SAFETY	4.1. Work Organization 4.2. Work Psychology 4.3. Occupational Biomechanics 4.4. Workplace safety 4.5. Analysis and Prevention of Accident Risks 4.6. Ergonomics 4.6.1. Product Ergonomics 4.6.2. Process Ergonomics
5. PRODUCT MANAGEMENT	5.1. Market research 5.2. Product Planning 5.3. Product Design Methodology 5.4. Product Engineering 5.5. Product Marketing
6. OPERATIONAL RESEARCH	6.1. Mathematical Programming 6.2. Multicriterial Decision 6.3. Stochastic Processes 6.4. Simulation 6.5. Decision Theory and Game Theory 6.6. Demand Analysis by Products

Area	Sub-area (continuation)
7. STRATEGIC AND ORGANIZATIONAL MANAGEMENT	7.1. Market Assessment 7.2. Strategic planning 7.3. Production Strategies 7.4. Entrepreneurship 7.5. Industrial Organization 7.6. Marketing strategy 7.7. Business Networks and Supply Chain Management
8. ORGANIZATIONAL KNOWLEDGE MANAGEMENT	8.1. Innovation management 8.2. Technology Management 8.3. Production Information Management 8.3.1. Management Information Systems 8.3.2. Decision Support Systems
9. ENVIRONMENTAL MANAGEMENT	9.1. Natural Resource Management 9.2. Energy Management 9.3. Industrial Waste Management
10. PRODUCTION ENGINEERING EDUCATION	10.1. Production Engineering Teaching Study 10.2. Study of the Development and Application of Research in Production Engineering 10.3. Study of Professional Practice in Production Engineering
11. PRODUCTION ENGINEERING AND SYSTEMS	
12. SUSTAINABILITY AND SOCIAL RESPONSIBILITY	12.1 - Sustainability Indicators 12.2 - Social Responsibility Indicators 12.3 - Sustainable Development and Production Engineering 12.4 -Social Responsibility, Ethics and Production Engineering

Source: ABREPRO (2021)