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Study on How New Technologies Have Been Used to Tackle Mobility Issues in Smart Cities

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ABSTRACT

Statistics show that the fertility rate has decreased during the last decades, but life expectancy has more than doubled during the last century. It indicates that there is a trend of more and more working-aged people traveling in the cities. It becomes more problematic when we look at the study of the United Nations which estimates that 55% of the world's population lives in urban areas and projects a proportion of 70% by 2050. This is a problem because most cities have not been planned to bear flows of people of this magnitude, and this is the root cause of most mobility issues that people face every day over the world. On the other hand, technological evolution has been outstanding in the last few years, and smart cities can make use of this advancement, especially to improve urban mobility. Examples of technologies that have been adopted in this field are the Internet of Things, Big Data, Artificial Intelligence, Intelligent Information Systems, and Intelligent Transportation Systems. This work aims to highlight the importance of all these tools in the application scenario of smart cities and, with this aim, brings an overview of each of them and a bibliographic review that shows how they are being currently discussed and adopted.

Keywords: Artificial intelligence, Big data, Intelligent information systems, Intelligent transportation systems, Internet of things, Smart cities

INTRODUCTION

The fertility rate in Brazil has dropped from 6.16 children per woman to only 1.57 children per woman in an interval of seven decades, from 1940 to 2014. In contrast, life expectancy has risen 41.7 years in little more than one century: whilst, in 1900, life expectancy was 33.7 years, in 2014, it reached 75.4 years (Cunha et al., 2022). According to the United Nations (UN), currently, 55% of the world's population lives in urban areas, and the prospect is that, by 2050, this proportion will be 70%. This is a problem because most cities have not been planned to bear flows of people of this magnitude, and this

is the root cause of most mobility issues that people face every day over the world (Teske et al., 2018).

Over the last decades, it has been possible to notice, nationally and internationally, that people's way of life has changed, aiming for the welfare of themselves and their families (De Haas, 2010). Therefore, there is a worldwide trend of people living near their workplaces, facilitating their daily mobility (Plaza et al., 2011). A study published in the Journal of Urban Economics shows, based on data from the Danish population, the preferences adopted by scientists and engineers for their workplace choices. The results achieved in that study indicate that technical workers show substantial sensitivity to wage differences, but they have stronger preferences for living near their families and friends (Demo and Cox, 2000).

Due to the aforementioned reasons, Intelligent Transportation Systems (ITSs) integrate information and technologies of data communication and applies them in the transportation field to develop integrated systems of people, roads, and vehicles (Guerrero-Ibáñez et al., 2018). ITSs can establish transportation management systems that are fully functional, accurate, and efficient (Shrestha et al., 2021), especially when they are integrated to Intelligent Information Systems (IISs), which involves data collection strategies to automatically record the system's information and parameters in the short and long term (Adler and Blue, 1998). Nowadays, data collection has become increasingly crucial for road transportation operations, especially concerning public transport, which creates a big data problem (Vlahogianni et al., 2004).

From this perspective, a quantitative methodology was adopted to identify scientific works that characterize the use of new technologies in smart cities, especially in the mobility field. This work achieved as results and conclusions a bibliographic review focused on the application of technologies in urban mobility, demonstrating the importance of this subject on the world stage.

This article is composed of four sections. The first one aims to present the problem that will be tackled by this research. The second section contextualizes, based on scientific references, the technologies that have been used to contribute to the development of smart cities and, especially, urban mobility. Section three presents the bibliographic review separated by subject area.Finally, the conclusion shows an overview of the research and highlights the importance of now technologies for public transportation management.

Conceptual Background

In this section, basic concepts that have guided this research will be presented to explain clearly and sharply its importance in national and international scopes concerning Smart Cities.

Smart Cities

There is not only one accepted definition for smart cities (Angelidou, 2015; Zanella et al., 2014), but the current understanding of this concept considers

a coherent urban development strategy managed by the government, which tries to plan the future of infrastructure assets and services of the cities aiming to improve the citizen's life quality (Kim, 2019; Komninos et al., 2014). With the massive proliferation of new technologies and smart devices, the perspective that a city can become smart and sentient is quickly coming true, and the convergence of information and communication technologies is creating urban environments that are different from everything that has been tried until now (Batty et al., 2012). When cities become smart, it is possible to automate functions that serve people, buildings, and traffic systems, and also monitor, understand, analyze, and plan the city to improve the efficiency, equity, and citizen life quality in real-time (Sundmaeker et al., 2010).

Internet of Things

In a few words, the Internet of Things is the concept of connecting any device to the Internet, creating a huge network of things, in general sensors, that collect and share data about the environment around them (Want et al., 2015; Paul et al., 2019; Jalali et al., 2015; Bi et al., 2014). The devices within the IoT universe are many, from autonomous cars, whose sensors are capable of detecting objects on the roads, to wearables that can measure heartbeats and count steps during a walk, for example. Even in the sports world, there are applications that use devices to send information about a match, such as soccer balls that can be tracked to determine the distance and velocity of a given move (Carling et al., 2007; Ren et al., 2009).

Big Data

The expression "big data" is extensive and was first used by NASA scientists to describe a problem of graphical computing. This issue was named "big data" be- cause it occurs when the dataset does not fit into the hardware's main memory or does not fit even into the local disk (Matturdi et al., 2014). Given the extension of this concept and lack of a formal definition, it is usually used imprecisely. However, the interpretation that better describes this concept is the one associated with a big set of information that could not be understood if it had smaller dimensions (Tsai et al., 2015).

Big data refers mainly to datasets that are too big and complex for being treated by traditional processing software (Taurion, 2013). The big data concept was initially associated with three characteristics (volume, variety, and velocity) that are related to the challenges of analyzing this kind of dataset: data collection, storage, sharing, transmission, visualization, query, and update, among others (Marx, 2013). When tools capable of dealing with big data were developed, two more char- acteristics were incorporated into the big data concept: veracity, which refers to the quality and reliability of data, and value, which is an intrinsic characteristic of data that is only known after proper analysis (Oussous et al., 2018).

Artificial Intelligence

Artificial intelligence (AI) is the behavior demonstrated by machines in opposition to the natural intelligence of humans and other animals. The most

relevant books about AI define its field of study as systems that sense the environment and perform tasks that maximize their chance to reach an objective (Winston, 1984). AI applications comprise advanced search mechanisms, recommendation systems, speech recognition, autonomous vehicles, and even competition in high-level strategic games, such as chess and Go (Rich, 1983). Each one of the mentioned applications has specific objectives and can be tackled by different tools, which include, but are not limited to, mathematical optimization, formal logic, artificial neural networks, and statistics (McCarthy, 2007; Hunt, 2014).

Intelligent Information System

Intelligence is the capability of learning, understanding, or dealing with new situations to reach an objective. Conventional machines have little intelligence because they are programmed to perform in the same way whenever they are used (Wiederhold, 1992). In other words, this kind of system performs well when there is no change in the environment where it is applied, but they fail in other conditions (Brooks, 1986).

Information systems that are built in the same way as static machines have high costs for creating, operating, and adapting (Wiederhold, 1992; Davis, 2009). To tackle this problem, there are two alternatives: improve static systems with the use of artificial in- telligence, a cheaper and more limited option, or create Intelligent Information Systems (IISs) capable of adapting according to their operation condition, which is the alternative that actually makes the difference regarding operational costs (Tekin, 2021; Clemons et al., 2017).

Intelligent Transportation Systems

Intelligent Transportation Systems integrate information and technologies of data communication and apply them in the transportation field to develop an in- tegrated system of people, roads, and vehicles, aiming at a management system that is fully functional, accurate, and efficient (Zhang et al., 2011). This concept was created at the beginning of the XXI century and is applied worldwide in all kinds of transportation systems (ground, water, and air) with the increasing interest in academic and industrial fields (Amin and Wollenberg, 2005), especially for the development of information and control technologies, which are the core of its functions (Joseph et al., 2006).

BIBLIOGRAPHIC REVIEW

Based on the references listed in Table 1, it is possible to observe that many technologies in the fields of the Internet of Things, Big Data, Artificial Intelligence, Intelligent Information Systems, and Intelligent Transportation Systems have been contributing to the development of Smart Cities. Within this scope, the area of urban mobility has been increasingly studied due to the many issues that exist about this subject in cities all around the world, especially large ones.

Table 1. Bibliographic review for each studied subject area.

Subject Area	References
Internet of Things	(Patel et al., 2019; Zhang et al., 2011; Al-Kadhim et al., 2019; Chauhan et al., 2020; Muñoz et al., 2018; Lakhan et al., 2021; Chavhan et al., 2019; Dhanalaxmi et al., 2017; Mittal et al., 2019; Kang et al., 2016)
Big Data	(Anda et al., 2017; Cottrill and Derrible, 2015; Mehmood et al., 2017; Milne and Watling, 2019; Cavanillas et al., 2016; Mehmood and Graham, 2015; Jovič et al., 2019; De Gennaro et al., 2016; Iliashenko et al., 2021; Borgi et al., 2017)
Artificial Intelligence	(Abduljabbar et al., 2019; Nikitas et al., 2020; Agarwal et al., 2015; Afan et al., 2016; Wu et al., 2022; Bramer et al., 2010; Štencl and Lendel, 2012; Boukerche et al., 2020; Wang, 2017; Kouziokas, 2017)
Intelligent Information System	(Dong and Paty, 2011; Gringmuth et al., 2005; Torrens et al., 2002; Alzoubi, 2018; Alabyan et al., 2016; Zhang and Wang, 2006; Deng et al., 2017; Im et al., 2018; Adler and Confer, 1998; Matvienko et al., 2015)
Intelligent Transportation System	(Fang et al., 2017; Figueiredo et al., 2001; Małecki et al., 2014; Yan et al., 2012; Mohan, 2007; Qureshi and Abdullah, 2013; Dimitrakopoulos and Demestichas, 2010; Richter et al., 2020; Wang et al., 2017; Bhat et al., 2016)

Scientific researchers have been developing more and more works that apply technological tools to improve urban mobility, seeking gains in many aspects that affect directly citizens that need to move around the cities: efficiency, health, savings, safety, and comfort, for example.

CONCLUSION

The technology comprises a set of tools that are extremely relevant nowadays for society as a whole, independent of the sector where they are applied. With technological evolution over history, many benefits have been brought to solve a wide variety of problems and, for urban mobility, it could not be different, since the definition of intelligent transport uses the logic that advances in technology must serve the citizens and help cities have sustainable development.

From this perspective, this work shows how technological advances have been affecting mobility within cities through the insertion of new techniques, which were addressed in the bibliographic review, to solve problems of many aspects, such as sustainability, economics, and welfare, and develop urban mobility that is more efficient and suitable for all stakeholders.

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