Systematic Review: Techniques and Methods of Urban Monitoring in Intelligent Transport Systems

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Abstract— **The process of urbanization and the formation of large urban complexes influence the increasing complexity for the planning, management and operation of urban mobility. Everyday problems related to urban mobility, such as congestion, quality of urban roads and inefficiency of public transport are evident, and can only be solved by the increase of technology and intelligence. Studies in Intelligent Transport Systems (ITS) act as an efficient solution to improve the functioning and performance of traffic systems, reducing congestion and increasing safety for citizens. With the objective of identifying and analyzing urban monitoring techniques, this article presents a systematic review of the monitoring techniques, in order to extract traffic behavior on the road in real time, making it possible to detect congestion, avoid accidents, among others Improvements to urban traffic. The significant benefit of this article includes a bibliographical research, based on the analysis of the problems related to ITS in function of the evolution, the variety and the complexity of technologies existing in the last years.**

Keywords- ***ITS; Urban Monitoring; Open Data; Smart Cities***.

I. INTRODUCTION

With the growth of urban centers and the need for agility and efficiency in access to services and information, connectivity plays a key and essential role in this global and digital interaction. In this context, the "Digital Cities" gain space and present themselves as a viable path, as can be observed in studies that point to the use of technologies in an urban context [1].

One of the main problems of urban centers today is mobility. The connectivity inherent to the "Digital Cities" opens a very promising frontier with regard to the control of access to information, as can be seen in the works related to ITS in China [2][3] and the distributed ITS architectures [4].

An ITS represents "the application of advanced sensors, computers, electronic devices and communication technologies and integrated strategic management, aiming to improve the safety and efficiency of the traffic management system" [5]. This interconnectedness of the "Intelligent Cities", when applied to the control of urban mobility, aims at the search of the efficiency in the displacement and fluidity of traffic and, consequently, an improvement of quality for the people that interact in this system and depend, directly, of the efficiency and Quality of this environment. According to Kim [6], "the speed of traffic is an important part in communicating the data. For engineers, this data complements other traffic information that reflects on road network performance and alerts of possible road traffic incidents. For drivers, the speed information reflects in the drivability. This is easily achieved, unlike other traffic data such as volume and density that are harder to relate to. "

However, these sources of Information and Communication Technologies (TIC) form complex structures and generate a large volume of data, which present great challenges and opportunities, making it difficult to offer programs that integrate sensor information and capture the physical space In real time. It is worth mentioning that open data initiatives are being carried out by governments at all levels in order to increase transparency, empower citizens, foster innovations and reform public services [2]. These initiatives converge with "Smart Cities" and different solutions are already in place in cities such as New York, Amsterdam, Helsinki, Chicago, Barcelona, Quebec City, Rio, Dublin, Nairobi and Manchester at different rates and scales.

In this context, the present article presents monitoring techniques with the objective of contributing to a better understanding and enrichment for the state of the art in ITS. It is worth mentioning that using these techniques, urban monitoring, has been extremely efficient, allowing a rigth and fast response for the community's needs, especially on intervention in traffic flow and safety. The most types of equipment and technological monitoring solutions are available for the safety and well-being of society. Some related works cited in this review, address several techniques, whether they are carried out in a simulated environment or real-time environment, but most of them do not follow policies of effective urban control, formalized by laws, norms and monitoring, that allows the coexistence and harmony between citizens, respecting the space of all.

The structure of the article is organized as follows. In section II, we consider the application of a systematic review to identify the techniques and methods of urban monitoring in ITS. In section III, a literature review to confront authors addressing the subject proposed. In section IV, an analysis and summary of selected papers about the subject researched. And section V, show the research findings.

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II. SYSTEMATIC REVIEW PROTOCOL

This section contains the protocol based on [7], which was used to apply the systematic review, whose focus of the searches, focused on the identification of the researches that present proposals related to techniques and methods of urban monitoring in ITS.

A. Formulations of questions

Question: What are the techniques and methods of urban monitoring in ITS that use/not Open Data?

B. Source Selection Criteria

Availability of query of articles in databases through the web (IEEE Xplorer, ACM Digital Library, DPLP Computer Science Bibliography), using the search field Title. The following search string used:

- (intelligent <and> transport <and> system) <and> (open <and> data) <and> (urban <and> monitoring)

C. Criteria for inclusion of articles

- Articles should be available for download on the web;
- The articles found must present complete texts of the studies in electronic format;
- Articles should be described in English or Portuguese;
- Articles that have been published in the last 5 years (between 2011 and 2016);

D. Preliminary screening process for primary studies

The search strategy will be applied for the identification of potential primary studies. With the studies researched, the title and summaries will be read. Given the relevance of a study, already highlighted in the abstract, it will be selected to be read in its entirety.

E. Final selection process of primary studies

It consists of the complete reading of the selected studies in the preliminary selection stage. The reviewers will be responsible for making a general summary and considerations on the results observed in the selected studies.

III. LITERATURE REVIEW

The ITS, aim to support the various everyday situations related to urban mobility, through the use of technologies and interoperability between communication systems, data transmission and connectivity.

Its efficiency in monitoring and agility in the distribution of information is essential so that the results regarding the optimization of transportation systems are felt by the general population that are included in this scenario, allowing a better management of the transportation system Urban [17][18].

The work of Nasim and Kassler [18] can be subdivided into six advanced management areas: Advanced Traffic Management System, Advanced Traveler Information Systems, Advanced Public Transport Systems, Commercial Vehicle Operating Systems, Advanced Vehicle Control Systems, Electronic Toll Collection. All these subsystems have the objective of acting in a specific and targeted manner on subareas of transportation management, seeking to guarantee the efficiency and quality of urban mobility.

According to the Open Definition [19], open data is data that can be freely used, reused and redistributed by anyone - subject to at most the requirement of original source allocation and sharing by the same licenses in which the information was presented. In other words, the opening of data is interested in avoiding a mechanism of control and restrictions on the data that are published, allowing both individuals and corporations, to exploit this data freely. From this perspective, the definition of the term open data presents three fundamental norms [20]: availability and access, reuse and redistribution and universal participation (areas of action and people / groups).

From the moment that there is a movement to make data available, where the three fundamental norms mentioned above are respected, it is possible that different organizations and systems can work in a collaborative way. This is due to the ability of these organizations and systems to interoperate the data that have been opened, thus increasing communication and enhancing the efficient development of complex systems [21].

IV. ANALYSIS AND SUMMARY OF SELECTED WORK

After the implementation of the Systematic Review Protocol (PRS), 83 scientific articles were initially identified (36 articles in the IEEE Xplorer, 28 in the ACM Digital Library and 19 in the DPLP Computer Science Bibliography), from the keywords used in the three databases. Data consulted. When the inclusion and exclusion criteria were applied in the reading of the title and abstracts of the articles, 6 articles were selected and analyzed in order to answer the two questions proposed in the PRS. The following is an overview of the work.

Jérôme et al. [8] show a platform that models and simulates applications within the scope of ITS. In the work is pointed out an open source framework, called iTETRIS, where it is formed by a set of other tools, each one having its specificities. These tools are: the Simulation of Urban Mobility (SUMO) framework that is responsible for simulating vehicle traffic; And a network simulator called the NS-3. In addition to these tools, there is a layer of control that does all management, keeping the data of each application synchronized. According to [8], the methodology used resources to analyze and manage applications, such as bus lane management, emergency vehicles, dynamic route planning, and the study of speed adaptation. This article also highlights the benefits that the framework can bring, such as reducing travel time, fuel economy or reducing pollutant emissions. Also mentioned are the characteristics that stand out over other works in the literature, where among these particularities mentioned in it, is the possibility of extending functionalities, precisely because it is an open source source. Despite the benefits mentioned in the article, it was not necessary to evaluate the studies in real environments, which would imply in the more loyal dimensioning of the results.

Ilya et al. [9] have an approach for monitoring traffic in large urban areas using drone technology. The authors state that the use of this technology offers innumerable

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advantages, such as: ease of access to irregular areas due to their small dimensions, coupling of several sensors to estimate general conditions of traffic in real time, independent monitoring of climatic factors, monitoring of offenders The creation of cartographic models of road traffic structures, among others. According to [9], Global Positioning System (GPS) technologies, although with high open-pit accuracy, may be inefficient with respect to the signal in areas of dense urban shading. Thus, in the absence of GPS signals, an analysis was proposed on the drone control system using a bimodal structure. The bimodal scheme allows the performance in safe mode of navigation. In case of a malfunction, the system allows the equipment to remain or return to the point of origin, thus avoiding possible accidents on public roads. This prototype was successfully tested for the monitoring of the transport infrastructure of the city of Orel (Russia).

Zan et al. [10] present an application was installed in the users' smartphone, where the personal data, the travel profile (origin, destination, purpose, location and time) and sensor data (GPS, time, and Accelerometer). During application operation, if your smartphone is connected to a power source and the connection is available, the data is automatically transmitted to the server. These collected data are analyzed for events such as congestion of frequent braking activities, speed and travel time variation. With this one can notify the drivers of the traffic condition and send driving recommendation so that they will be able to make informed decisions. Due to the smartphones used by the users of different brands and models, it resulted in the inconsistency of the data collected. This issue has to be resolved in future implementations.

The results of Fayazi et al. [11] are based on data from bus movements in the city of San Francisco. Data bus power is provided by NextBus to a number of cities in North America in XML. The attributes of interest are the position and speed of each vehicle along with its weather identifier and the bus identification number. In addition, bus route data and bus location locations were extracted from the same data stream. Fayazi et al. [11] also demonstrated the feasibility of timing estimation of fixed-time traffic lights, for example, at intersections in the city of San Francisco the feasibility of estimating cycle time, red signal time, green signal start, Change of signal programming. The extensive use of filtering / preprocessing data is elementary to the successes found in [11]. It is noted that the influence of heavy traffic conditions on the prediction is not investigated in this work neither the adaptive signals were considered.

Shi et al. [12] used the Bayesian Logic model to predict in real time. The probability of an accident occurring, logistic regression models were evaluated under Bayesian conditions. Therefore, this statistical method is able to handle information from different sources. With the rapid development in Big Data, it is expected that new data sources can be incorporated into this modeling framework in the future.

Unlike other previous real-time traffic safety studies, Shi et al. [12] incorporate a reliability analysis to determine the conditions under which it is appropriate to trigger safety warnings on the expressway. The First-Order Reliability Method (FORM) model was constructed based on the real-time fall forecast model and based on the critical point of the CI system, where volume and velocity were obtained. It was found that the average peak IC for failures per hour was equal to the congestion threshold, which suggested that when congestion is detected at a specific location, both congestion and safety warnings should be sent to drivers. Also in [12], a method of combined real-time congestion and safety monitoring in urban expressways was proposed through the Multipoint Video Distribution System (MVDS) system.

Wang et al. [13] designed a monitor urban traffic using the Markov model to measure the estimated traffic accuracy according to vehicle position and speed. This model takes into account the mean, variance, and correlation of the traffic in a particular stretch of road being mapped over a given period with the impact of granularity on the accuracy of traffic estimation so that we can measure the quality of service in the system through Granularity function.

Santos et al. [14] method can be conceptualized as: rule, norm, search for truth, detection of errors in the attempt to achieve a desired goal. Some authors, in defining method, emphasize intelligence and talent in the way they perform tasks. Others focus on the aspects of order, path, security and economy in the accomplishment of an activity.

Lakatos et al. [15] show that among various concepts of methods we can mention: Method is the "path by which a certain result is arrived at, although that path has not been fixed in advance in a reflected and deliberate way".

Method is a way of selecting techniques for evaluating alternatives to scientific action. So, while the techniques used by a scientist are the fruit of their decisions, the way in which such decisions are made depends on their decision rules. Methods are rules of choice; techniques are their own choices " [15].

Method is also the way to proceed along a path. In science, methods are the basic tools that order the thought of systems in the first place, and in an orderly way the scientist's way of proceeding along a path to achieve an objective.

The term method already existed in classical Greek (méthodos), having been used by Plato and Aristotle in the sense of "ordered study of a philosophical or scientific question". The word can be decomposed into the prefix metá + hodós, which means path, path, route. In the generic sense, therefore, it is the "way by which a certain result is arrived at". In scientific terminology, method can be defined as a set of data and rules to proceed, allowing to reach a predetermined end.

Marconi et al. [16] technique is a set of precepts or processes that serve a science or art; this technique allow him to bring the teorical norms to the practice. Marconi’s technique defines the way of proceeding in its smallest details, the operationalization of the method according to standards. It is a result of experience and requires skill in its execution. The same method may involve more than one technique. The semantic difference between method and technique can be compared to that between gender and species.

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In order to discover and analyze the techniques and methods most used in the selected articles, the techniques and the monitoring methods present in each article, set out in Table 1 and 2, were identified where the symbol "✓" indicates the existence of the observed characteristic:

TABLE I. MONITORING METHODS

Methods	[8]	[9]	[10]	[11]	[12]	[13]
Traffic Management				✓	✓	
GPS monitoring		✓	✓			
Drone Monitoring		✓				
Camera Monitoring		✓				
Combined Real Time Monitoring					✓	

According to Table 1, it is possible to note that the most used methods are: "Traffic Management", with two articles; And "GPS monitoring", also with two articles. It is assumed that these characteristics were the most used, as they are responsible for managing the traffic and obtaining the location of the transport, respectively.

TABLE II. MONITORING TECHNIQUES

Techniques	[8]	[9]	[10]	[11]	[12]	[13]
Framework for simulating vehicle traffic	✓					
Markov model						✓
Open Data Approach	✓			✓	✓	
Use of Monitoring Software		✓	✓	✓	✓	✓
Data Mining			✓	✓		✓
Bayesian Inference					✓	
MVDS					✓	
PHP Web Interface Monitoring				✓		

With regard to the most used techniques shown in Table 2, we have: "Open Data", with three articles; The "Monitoring Software", with five articles; And the "Data Mining Technique", with three articles. It is assumed that these techniques were the most used for being responsible for obtaining traffic data in order to analyze and perform urban monitoring to find a better solution.

The author of [22] presented some techniques of traffic analysis focusing on urban environments. As an example, we have the automatic monitoring by video, through urban surveillance cameras, aiming to observe congestion, interaction of vehicles and check violations of traffic rules. Because of these problems, different classifying algorithms were presented in Buch et al. [22], that the authors created in order to classify the vehicles and increase the capacity of detection level and tracking. The use of these cameras became feasible because of the reduction of the cost (hardware), causing a great ascendancy in the implantation of these cameras, making possible and facilitating the analysis of the urban traffic. This area is of great interest to ITS and offers several future challenges, such as some assessments in challenging weather conditions, among others.

Through the methods and techniques of urban monitoring in ITS we can demonstrate that there are several advantages related to our suggested approach. The innumerable advantages using technologies are increasingly improving the way in which we can use these techniques and methods for the development of field research. The advantages are monitoring traffic offenses, weather factors, locating vehicles by GPS, improving traffic congestion through traffic lights, etc.

We propose that ITS, along with these methods and techniques described in this article, bring a better development in vehicle traffic monitoring so that we can differentiate alternative routes from vehicles in congested areas. ITS is increasingly improving through existing technologies in order to provide better distribution of vehicles on a given route. Monitoring methods and techniques are conducive to better tracking of alternative routes through applications that can assist vehicle drivers through these routes and demonstrate the estimated time of their commuting from one location to another.

V. CONCLUSION AND FUTURE WORK

In this article, work related to the area of intelligent transport systems was considered. With the purpose of identifying and evaluating urban monitoring techniques. A systematic review was presented on the monitoring techniques, in order to extract traffic behavior on highways, making it possible to detect congestion, avoid accidents, among other improvements for urban traffic.

Due to the investigation, it was noticed how small a number of articles correlated with the search theme, this shows that the research area is relatively new and at the same time shows a research path to be explored.

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