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RESEARCHES AND APPLICATIONS OF INTELLIGENT TRANSPORTATIONS SYSTEMS IN URBAN AREA: SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

The purpose of this paper is to systematically review evidence of existing ITS research that could be effective in mitigating current problems in City Logistics. We systematically searched the English and French languages literature indexed in Scopus (2010 to July 2018), including: Elsevier, ACM, Springer, and IEEE. We also added studies identified by experts up to July 2018. The study selection was descriptive and comparative studies and systematic reviews of Intelligent Transportation Systems. Therefore, we independently extracted information on ITS subsystem capabilities & development and technologies used. 56 studies met the inclusion criteria, some were in the research and development stage, while others have seen some measure of application or deployment. Most studies addressed Advanced Traffic Management Systems (ATMS), Advanced Public Transportation Systems (APTS) and Advanced Traveller Information Systems (ATIS). Data on efficiency measure, technologies used were mixed. Empirical cost data were limited. This study has a number of implications. Practitioners and researchers will gain a greater understanding of how ITS are carried out in developed countries and the type of challenges that have been addressed. Furthermore, the results provide insights about the research path, current technologies and future research directions in the field of ITS.

Keywords: intelligent transportations systems (ITS), city logistics, advanced traffic management systems (ATMS), advanced public transportation systems (APTS), advanced traveller information systems (ATIS).

1. INTRODUCTION

Intelligent Transportations Systems were originally designed for use to face the saturation of the transportation infrastructures (M Alam, *et al,* 2016 [1]) due to the growing number of vehicles and the rapid urbanization over the last five decades, Figure-1. This situation affects people lives mainly in the urban areas, while we need, progressively, to move quickly between different places. The results are accidents, traffic congestion, transportation delays and larger vehicle pollution emissions. ITS were introduced to reduce these problems or their outcomes. However, the fact that they are more difficult to implement in developing countries (H Quak and N Nesterova, 2014 [2]) Compared to developed countries, which are easier for implementation.

Despite the challenges related to urban area, there is an industry trend towards deploying ITS in cities (K Sjoberg, *et al*., 2017 [3]; L Zhuhadar, *et al*., 2017 [4]). Since that, their shown and potential benefits have made them attractive. Examples are multiple in both developed and developing countries. Nevertheless, currently it is clear that constructing more roads to reduce traffic congestion is not the "Good" solution, because is more expensive, while causing a significant environmental impact, besides requiring a more space, which is a vital limitation within urban areas. On the other hand, it is also straightforward that the improvement of the transport infrastructure is essential for the economic development. So, the new researches on ITS must take in consideration this.

The State of Intelligent Transportation Systems that BH Lee *et al.,* [5] has conducted by 2011, discussed a few problematics related to urban area as well, e.g. Authors regard the traffic problem as not only a problem for individual countries, but also a global topic by providing a comparison and analysis of international ITS research and development.

As literature contains several research studies, experience reports and cases studies on ITS applications in urban area, a systematic overview and synthesis of this growing body of research is still missing. In this paper, we start filling in this gap by giving a systematic literature review of researches and applications of ITS in urban area.

The sample of our study is limited to some selected subset regions (U.S.A, Japan, and European Union). However, this indicates that there seems to exist a large number of countries that have implemented or are implementing ITS technologies.

This SLR is considered a valuable addition to the available ITS literature, and will allow readers not only to take an overview of research and technologies recently developed in the field of ITS, but also to give practitioners a clear picture of the main challenges faced in the adoption of ITS in cities.

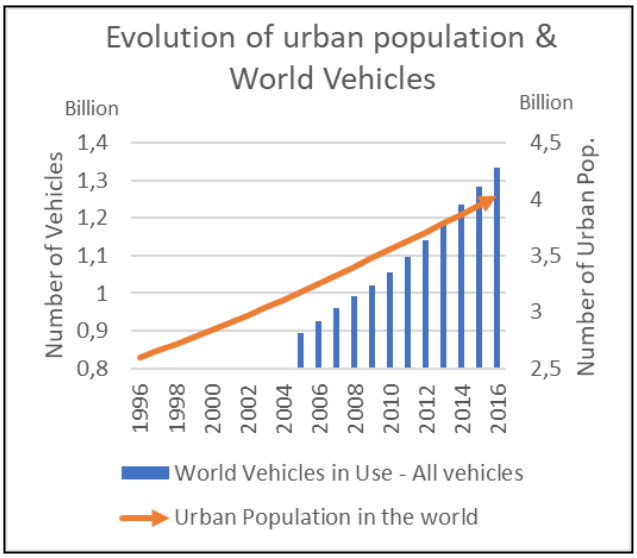

Figure-1. Evolution of urban population & world vehicles in use (1996-2016) [6].

2. BACKGROUND

A. Definition of intelligent transportation systems

From a research point of view, we identified a number of a brief literature search discussing and interpreting of what ITS is. Y Lin *et al*., 2017 [7] consider that Intelligent Transportation Systems is the application of detection, analysis, control and communication technologies to transportation in order to improve mobility, safety and efficiency. ITS includes a varied range of applications that process and share information to improve traffic management, reduce congestion, ease environmental impact and increase the benefits of transportation for both commercial users and citizens, as represented in Figure-2.

In early work on ITS, Figueiredo considers that ITS is applying advanced communication, information and electronics technology to solve transportation problems such as, traffic congestion, safety, transport efficiency and environmental conservation (Figueiredo *et al*., 2001).

Therefore, on the institutional level, the ITSS's constitution defines ITS applications as "those systems utilizing synergistic technologies and systems engineering concepts to develop and improve transportation systems of all kinds" [8]. And according to the Directives of the European Union on Intelligent Transport Systems [9], ITS are advanced applications which without embodying intelligence as such aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated and 'smarter' use of transport networks.

Other recent studies [10], [11] have referred to ITS as a part of the Internet of Things, includes vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-everything (V2X) technology and big data analytics in order to connect vehicle information and location to other vehicles, other transportation modes (such as pedestrians

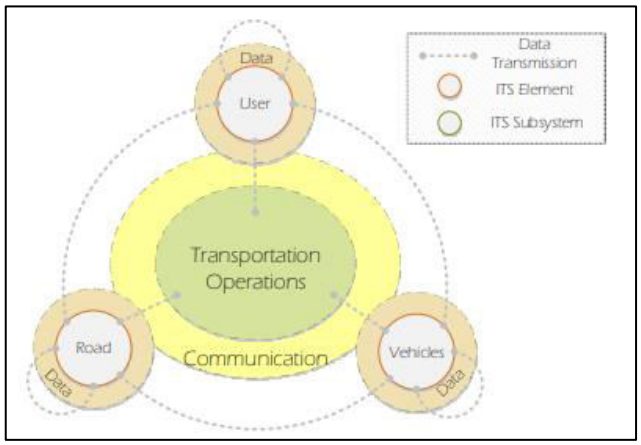

Figure-2. ITS conceptual model [7].

or bicyclists), local infrastructure and remote infrastructure in the cloud. It been clear that, the evolution of challenges, technologies, and growing needs of users has affected directly the context of what is seen as ITS. Although, we have cited the definitions that we consider to be the most important and that mark the evolution of ITS concept. Figure-2, represent the communication between the three main elements of ITS (User, Road and vehicles), by sharing and transmitting data in real time.

B. Evolution of intelligent transportation systems

While research and applications of ITS in urban areas are accumulating and growing in different countries and through different subsystems, most research and reports claim that ITS development started in the 1980s. The main ambition was to fully integrate sustainable development, in all its components (environmental, social and economic), and transportations challenges, into national policy.

Based on the bibliographic analysis performed, we found that researches on ITS were dominated by U.S.A followed by Japan and European Union researchers and institutions. Indeed, most of research literatures indicate that the main development on ITS were made in thus three regions (U.S.A, Japan and European Union) [4]. However, papers that presents clearly the history timeline of ITS were limited. Lino Figueiredo *et al* [13], consider that ITS development has gone through three phases: Preparation (1930-1980), feasibility study (1980-1995) and product development (1995-present). Therefore, James Bunch *et al.* [12], presented the ITS development through four generations: First Generation ITS 1.0 (1980-2000), Second Generation ITS 2.0 (2000-2003), Third Generation ITS 3.0 (2004-2005) and ITS 4.0 (2006-present).

Although, based on the results of such papers, and the other government and local reports [14], [15], which presents the history of ITS in the country / region involved. We have established history time sheet with a global perspective Table-1. Through this time sheet, we have tried to combine the different historical pervious works by distributing it into six main periods, which are Preparation (1970-1980), Feasibility study and research (1980-1990), First Generation ITS 1.0 (1990-2000),

Second Generation ITS 2.0, Third Generation ITS 3.0, and ITS 4.0 (2015-present). Some main ITS technologies examples are given for each period in order to have a clear idea.

ITS deployment methods emphasize that planning is only meaningful for the near future. However, the lack of planning can be a concern as PPP Public-Private Partnerships often build on long-term road mapping. Enabling operation with shorter term planning requires educating urban stakeholders and reviewing contracting practices.

Table-1. Time sheet history of ITS evolution (1970-Present).

	Period	Phase	Main Technologies	Examples
1	1970-1980	Preparation		
2	1980-1990	Feasibility study and research		
3	1990-2000	First Generation (ITS 1.0)	Arterial Traffic Management	
			Traffic Management Centers	
4	2000-2010	Second Generation (ITS 2.0)	"Smart cars" Systems	Route Destination & Driver Information Display
				Vehicle Diagnostics
				Smart Card Reader & Silent Alarm
				Automated Fare Collection and Passenger Counting
				Traffic Signal Priority
				GPS & Vehicle ID
			Traveler Information	
5	2010-2015	Third Generation (ITS 3.0)	Electronic Tolling & HOT Lanes	Trafic monitoring camera
				Lane side computer
			Mobile Devices	Traffic & Navigation
				Parking Info & Guidance
				Ride-Hailing & Carpooling
6	2015-present	ITS (ITS 4.0)	Automated, Connected, Cooperating, Electric Vehicles	"V2V" : Vehicles to Vehicles
				"V2I" : Vehicles to Infrastruture
				"V2X" : Vehicles to everythings
			Big data analytics	Building Insights
				Mobile Asset Insights
			Connected infrastructure	Logistics Safety
			Connected Fleet	Logistics Networks

C. Applications of ITS in Urban Area

The difficulty of introducing ITS technologies increases in the urban area, and more specifically in the developing countries (H Menouar, *et al.*, 2017 [16]).

The difficulty is partly related to the higher institution inertia, which slows down territorial / technological change. ITS development is not founded on the use of individual solution or technology, but rather on a holistic way of thinking. Adopting ITS often requires change of the entire culture in the involved environment (G Kant et al., 2016[17]).

Urban area has more dependencies between Public institutions. This increases the need for formal documentation and approval of different stakeholders and thus reduces agility (Juan Antonio, *et al.* 2015[18]). For instance, all institutions affected by the ITS deployment need to be informed and consulted, and the deployment process must be adjusted according to their requirements.

ITS deployment affects directly the PPP (Public-Private Partnership) management and institutions-citizen related services. A key challenge is that ITS adoption must move away from life-cycle models and towards iterative and feature centric models (DIMITRAKOPOULOS George, 2011[19]), which requires a change of mind-set. The focus must be shifted from long-term planning to shorter term project planning (Y Lin *et al.*, 2017 [7]), as ITS deployment methods emphasize that planning is only meaningful for the near future. However, the lack of planning can be a concern as PPP Public-Private Partnerships often build on long-term road mapping. Enabling operation with shorter term planning requires educating urban stakeholders and reviewing contracting practices.

Solutions and technologies developed in STI projects have been both criticized and advocated, and research has shown that accommodating change and current challenges may be a factor in both success and failure of urban development (G Kant *et al.*, 2016 [17]). It has been shown that ITS technologies have improved satisfaction of both citizens and local institutions, but on the other hand there is evidence that ITS technologies may not be a right fit for every urban area (COTRELL, J., *et al.*, 2014 [20]). A proposed solution is that each urban area seeks its own balance of ITS technologies / infrastructure and plan their adoption and deployment process (BB Rhoades and JM Conrad, 2017).

3. RESEARCH METHOD

A. Research questions

Systematic literature review is a method of identifying, evaluating and interpreting all available research literature relevant to a specific research question, or topic area, or phenomenon of interest. It is appropriate for summarizing existing research, for identifying gaps in the existing literature, as well as for providing background for positioning new researches (B Kitchenham *et al.*, 2004 [21]).

In this paper, we present the results of a systematic literature review on the topic of Intelligent Transportations Systems. The review is positioned in, and utilizes the literature of, the field of city logistics. In the review, we study the following research questions:

- **RQ1:** What researches and solutions have been developed so far in the field of Intelligent Transportation systems?
- **RQ2:** What challenges have been reported for ITS applications in urban area context?

While Intelligent Transportations Systems could provide many viewpoints to use as research questions, we chose these two questions because we consider they represent the viewpoints, which are likely to provide actionable insights to researchers as well aspractitioners. The research questions are intended to present complements to each other by highlighting different characteristics in the existing ITS deployed in countries that could be effective in mitigating problems in urban area.

Research process

The research process consisted of four key steps represented in Figure-3, the selection of primary studies was done in two steps first using keyword-based database searches to identify potentially relevant sources, and then manually filtering the search result. The two authors executed the manual filtering process independently. Data extraction was done by qualitative coding of the selected primary studies by the first author. Finally, the results were elicited by aggregating and analysing the coding of the primary documents. The entire process was audited and mentored by the second author.

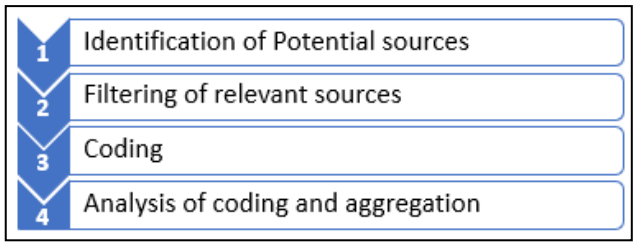

Figure-3. Summary of research process.

a) Inclusion criteria

Based on the research questions and focus of the research, we defined four facets to guide our inclusion/exclusion decisions: Intelligent Transportations Systems research & development, Intelligent Transportations Systems applications, Urban Logistics, and Empirical. Table-2 lists the facets and gives examples on matching topics and irrelevant topics. For a study to be included, it need to be relevant on all facets.

The facet of Intelligent Transportation Systems research & development was interpreted according to the existing literature review of ITS development, feasibility studies on ITS application and official institutional reports discussing ITS research & development.

We included also, studies of institutions that focus on ITS development, as well as the parts of larger (non-ITS focused) organizations that develop new technologies in different area, that can contribute to and improve the results of our review.

We excluded paper discussing Intelligent Transportation Systems technical architecture since that it is not relevant to our research questions.

Table-2. Inclusion criteria.

Facet	Relevant topics	Examples of non-relevant topics
Intelligent Transportation Systems Research & Development	Literature review of ITS development, feasibility studies on new ITS application, official institutional reports discussing ITS development.	Intelligent Transportation Systems architecture.
Intelligent Transportation Systems Applications	Present insight about the deployement process, application challenges and Benefits.	Non reputable source that discuss the ITS adoption.
Urban logistics	ITS implemented by cities in the selected countries (U.S.A, Japan, France and Germany)	ITS implementation in outside of the selected countries
Empirical	Case studies, implementation reports	Students experiments, theory paper

The facet of Intelligent Transportation Systems applications was interpreted so that the primary study had to present insights on the real case application and challenges of ITS deployment. In some cases, the source presented very vague indicators on ITS technology adopted. For instance, one case (EL FAOUZI, Nour-Eddin, *et al.*, 2011 [44]) was included, as there were indications of challenges of ITS adoption, although the ITS technologies used remained unclearly presented. If there were no indications of ITS technology adopted, the paper was excluded.

Examples of excluded paper are non-reputable source that discuss the use of ITS in urban area, and merely presenting ITS tools in urban context.

The facet of urban logistics, we required that ITS were aimed at introducing in urban area of the developed countries, after our first research we decided to restrict the scanning on four regions: the USA, Japan and European Union. The Four countries were selected because of existing and emerging applications of ITS strategies that had resulted in measurable improvements in urban logistics.

We excluded the application of ITS which not affect the performance of transportation inside urban area.

According to the facet of empirical, we excluded studies that did not deal with a distinguishable real-world case. We excluded textbooks, studies that only presented theories, as well as studies that did not include any cases of urban area. In addition, we excluded studies on the benefits or limitations of ITS in general. Finally, we excluded students' experiments because it is implausible to draw conclusions about the outcome of adoption.

b) Preliminary searches

Before proceeding with identifying the primary studies several preliminary searches were performed. The purpose of the preliminary searches was to develop and evaluate different search strings. In addition, we used the searches to identify a set of relevant papers that should be matched by the actual search. We started by looking at the most highly ranked occurrences by trivial keywords that the final search string could miss. Initial searches were conducted using keywords as general as possible, including "Intelligent Transportations Systems" and "urban logistics".

Based upon these preliminary searches, we selected 103 papers that seemed relevant from the title. We used this set as a «mind check» when developing the database search.

The collection of potential initial studies was based on a search of the on-line databases mentioned in Table-3. Based on the previously discussed facets, we constructed a search string. Nevertheless, our initial research has shown that it is difficult to choose keywords with good accuracy. Particularly, we have not been able to represent urban area and empirical facets with specific words. Consequently, we only included research and development of Intelligent Transport Systems and their applications in the keyword search, which translates into an increased manual filtering effort in the following steps. The keywords used are indicated in Table-4.

Table-3. Databases included in search, and number of matched articles.

Database	URL	# of matches
IEEEXplore	http://ieeexplore.ieee.org	614
Elsevier (ScienceDirect)	https://www.elsevier.com/	289
Taylor and Francis	https://taylorandfrancis.com/	104
Springer link	https://link.springer.com/	79
The TRIS and ITRD	https://trid.trb.org	68
Researchgate	https://www.researchgate.net/	65
Google Books	https://books.google.com/	59
ACM Digital Library	http://dl.acm.org	32
HAL	https://hal.archives-ouvertes.fr/	28
MDPI	www.mdpi.com/	17
US ITS Institutions Report		35
Europe ITS Institutions Reports		26
Japan ITS Institutions Reports		23
Total		**1437**

d) Study selection

All the potential primary studies identified by the database search were refined in two stages, first by filtering based on abstracts and finally based on the full text. The study selection process is described in Figure-4.

c) Identification of primary studies

Table-4. Facets and related search terms used.

Facet	Keywords used in English	Keywords used in French
Intelligent Transportations Systems research & developement	ITS, "Intelligent Transportations Systems", "Intelligent Transportations Systems developement", Intelligent Transportations Systems developement, "Smart parking", Intelligent Transportations Systems "systematic review".	STI, "Systems de Transport Intelligents", "Developpement des Systems de Transport Intelligents", Developpement des Systems de Transport Intelligents.
Intelligent Transportations Systems applications	(Applicat*, Implement*, Adopt* introduc*, Deploy*) of ITS in (=Name of country or (=Name of city)), Smart Parking in * (=Name of city), intelligent transportation systems "application benefits", Intelligent Transportations Systems "review".	(Applicat*, Implément* Adopt* Mise en place*) des STI au sein (=Nome du pays ou (=nom de la ville)), bénéfits de la mise en place des systems de transports intelligents, applications des systèmes de transports intelligents revue de litterature.
Only applications on urban area related articles	Intelligent Transportation Systems in urban area, Smart cities "benefits", Smart cities "review".	Application des Systems de Transport intelligents dans les villes, STI et logistique urbaine, STI et Transport urbain.

The keyword search in the database matched 1437 unique articles. The abstracts of these articles were categorized independently by the two authors into three categories: include, exclude, and uncertain.

The two researchers agreed on 1184 exclusions and 62 inclusions. The inclusion decisions for the 191 abstracts with uncertainty or disagreement were resolved through discussion.

At this stage, articles were excluded only if both researchers considered it clearly irrelevant, including uncertain cases for full text filtering. As a result, 143 articles were selected for full text filtering.

Full text filtering was conducted by evaluating the text of each article against the four facets of the inclusion criteria. Filtering was done in two stages. In the first stage, the first author extracted data relevant to the four facets. Based on the extracted data, 65 papers could be immediately considered as included or excluded. The remaining 78 papers were evaluated against the inclusion criteria by the two authors, and a decision was made after discussing each paper separately. Following full text filtering, 50 articles were selected for inclusion.

We assessed the keyword search result in the database against the benchmark created in the preliminary search step. We concluded that 71 of the 103 articles previously selected were matched by keyword searching in the database. The 32 missing preliminary articles were reviewed, resulting in the inclusion of four additional articles as primary sources.

In parallel with the full text filtering step stage, the relevance of the references of all 143 articles selected for full-text filtering was also examined. Most articles used very few references, generally referring to well-known descriptions of intelligent transport systems. This step led us to include two additional articles in our analysis of the full text.

As a result, we selected 56 articles for inclusion in the analysis phase.

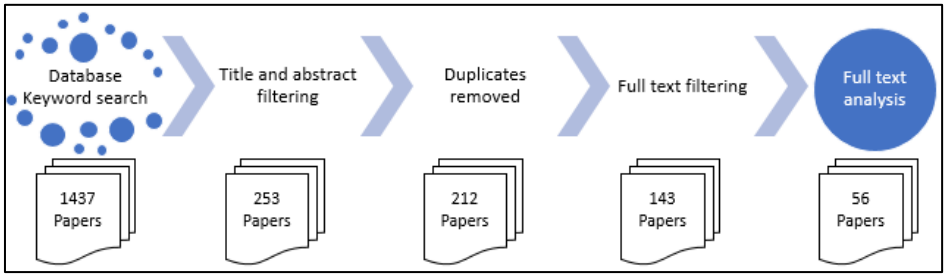

Figure-4. Outline of the research selection process.

e) Handling of duplicate reports on a single case

In several cases, more than one primary study focused on the development and applications of the same ITS technology. Duplicate descriptions generally focus on different aspects. For example, one article would highlight the R&D perspective on ITS and another would examine ITS applications from the perspective of user experience.

Although ITS applications in a single urban area were described in several studies, all sources that met the inclusion criteria were included. Studies with the same urban area were treated as a single unit so that we could obtain as much information as possible on each urban area. Conversely, there were also a few articles that presented multiple case studies, and in these cases, we treated each urban area studied individually.

Rather than using the most complete article as proposed in the guidelines for systematic literature reviews (B Kitchenham *et al*., 2004 [21]), we combined the results represented in each article and considered the case as a single unit in our analysis. Bearing in mind the potential bias caused by duplicate publications, we believe that the inclusion of all articles allowed us to gain a deeper understanding of individual cases.

As a result, we identified 52 new technologies in the primary studies. We use the term study to refer to the primary publications, and the term case to refer to an individual case urban area that may be described in several different ITS studies.

f) Study quality assessment

The primary studies for this systemic literature review are almost exclusively research papers. We identified only seven experience reports with clearly defined case studies. Therefore, observations on applications were only presented as a minor part of research papers. Based on this finding, we conclude that case studies of ITS applications in urban areas are very rare. We thought that the results would be highly biased and that many valuable studies would be left out if a strict quality assessment were part of the inclusion criteria. Therefore, we have decided to include all experience reports, regardless of potential author bias and publication problems.

g) Coding of primary studies

We coded the primary studies following a deductive approach, coding both applications report and research studies (DS Cruzes and T Dyba - 2011 [22]). We established a list of codes for contextual information (Table-5), which included urban area/Country, Urban area size; Reason to implement ITS, ITS subsystems, Key technologies, ITS Service and Challenges. These codes related to the research questions were created by a deductive process to avoid having our previous assumptions affect the choice of codes.

It should be noted that in this paper, we deal only with outcomes related to the challenges and as such, they are part of a larger study.

h) Synthesis of primary studies based on coding

We summarized our findings by creating an initial organization of codes into high-level categories based on code labels. Each code has been classified into a single category. After each code was assigned to a unique category, the content of the categories was reviewed. Each category has been studied by reading each citation of each code included. Typically, citations were posted and reviewed in their original context, taking into account the

surrounding paragraphs of the citation. Notes were taken on each citation presenting observations of interest. We used the notes to create a concise description for each code.

Then we refined the categories according to the concise descriptions. Some codes have been reclassified and the definitions of some categories have been revised until a final order is reached. The results are presented based on the final categorization.

Table-5. Context information extracted from studies & reports.

Contextual code	Explanation
Urban area, Country	Urban area in which the ITS is used/Operates
urban area size	Mentionning the size of the urban area
Reason to implement ITS	Reason to start the developement/implementation of ITS
ITS subsystems	ITS subsystems developped/used in the urban area
Key technologies	Key technologies / results the studies focuses on
ITS services	Services covered by the ITS adopted
Challenges	Statements presenting challenges of the ITS applications

4. RESULTS

In this section, we present our findings. First, we present an overview of the studies. Then, we discuss the results organized according to our two research questions.

A. Overview of the primary studies

In this section we present the type of the primary studies, some characteristics of the ITS research & solutions, as well as the ITS applications challenges in urban area.

a) Study types

The results include findings from 56 primary studies discussing the main ITS technologies and solution developed, deployed & used in urban area. Most studies were research papers (49 studies). Only seven of the included studies are experience reports contained ITS applications explicitly detailed. The publication forums of the selected papers were distributed so that 29 sources were conference proceedings, 20 sources were journal articles and seven sources was an institutional experiences report. All studies and reports included were dated after year 2010.

b) ITS Subsystems

The complete results related to the ITS subsystems are too large to be totally included in this review; therefore, we selected the most significant papers relevant to our research questions. The result is presented into eight major subsystems [12], Table-6.

The proposed subsystems exclude the application of ITS outside urban area, e.g., Advanced Rural Transportation systems (ARTS).

Table-6. Percentage summary of ITS studies & cases by ITS subsystems.

ITS Subsystems	% of cases
Advanced Traffic Management Systems (ATMS)	63%
Advanced Public Transportation Systems (APTS)	25%
Advanced Traveler Information Systems (ATIS)	21%
Commercial Vehicle Operations (CVO)	21%
Transit Management Systems (TMS)	17%
Emergency Management Systems (EMS)	13%
Advanced Vehicle Control Systems (AVCS)	13%
Incident Management Systems (IMS)	8%

Results show that the most prevalent ITS subsystem was ATMS, which represent the sole subsystem mentioned in 63% of cases. The second most mentioned ITS subsystem was APTIS and ATIS (in 25% of cases). Although, it was quite common that researchers sought to combine ITS subsystems in the same paper which led us to consider it in our analysis.

c) Urban areas case

Some urban areas were represented quite evenly in the selected countries. According to the result of our research, U.S.A was the most represented by 39% of cases (including cities such as New York, Seattle, Las Vegas and California). The second most represented country was Japan by 31% of cases. Followed by European Union by 26%, while in 4% of studies there was no direct indication about the urban area / Country. Table 7 summarizes the Percentage of ITS studies & cases performed by the selected countries.

Table-7. Percentage summary of ITS studies & cases by countries.

Counries	% of cases
U.S.A	39%
Japan	31%
European Union	26%
Undifined	4%

B. ITS Researches and development studies

In this section, we answer our first research question, RQ1: What research and solutions have been developed so far in the field of Intelligent Transportation systems? We organized the results, into eight subsystems, which are elaborated in this section and summarized in Table-8.

The table present the subsystems of ITS. We have included list of references to the primary studies and key technologies / results that the studies focus on. The purpose is to give the reader an idea about the main technologies and solutions developed in the selected countries.

C. ITS Applications in urban area cases

Any applications of ITS in urban area involve challenges. In this section, we answer our second research question RQ2: What challenges have been reported for ITS applications in urban area context? We organized the

challenges that slowing up the development and implementation of new ITS solutions into six categories. The categories are summarized in Table-9.

The table presents the challenge categories, lists references to primary sources and experience reports. We have included a count of the number of individual cases and references mentioned for each factor, and a percentage of that count against the application challenges category. The purpose of these counts is to give the reader an idea of how often the factor was mentioned. We would like to note that the frequency of mentions alone is not verifiable evidence of the real importance of the factors.

5. DISCUSSIONS

In this section, we first discuss our general observations, followed by a discussion regarding the answers to our research questions. Next, we identify discrepancies and outstanding issues in the literature. Finally, we discuss the limitations and present a research agenda for future works.

A. General observations

The primary studies identified were almost exclusively research documents. We could only find seven experience reports. None of these research papers directly addressed ITS application challenges, although they also provided information on the deployment process. As shown in our relevance classification in Table-8. 24 research papers received classification 2, while 18 received 3 and one received 4 (with a scale of 1 to 5, where 5 means the entire article focuses on describing the results related to our two research questions). While the experience reports were better focused on describing the challenges.

Moreover, belong mentioned challenge in our primary studies rose the “Lack of information about existing and new ITS applications and initiatives”.

B. Answers to research questions

This section summarizes and discusses the answers to the research questions.

As an answer to RQ1: “What researches and solutions have been developed so far in the field of Intelligent Transportation systems?”, we identified 52 new technologies from 2010 until July 2018, the result is grouped into eight subsystems, as presented in Table-8. The ITS subsystem that stand out are: 1) Advanced Traffic Management Systems (ATMS) (63%), 2) Advanced Public Transportation Systems (APTS) (25%) and Advanced Traveller Information Systems (ATIS) (21%).

These results clearly explain the growing interest of researchers in the topic of ITS as far as their applications in urban area. Moreover, it was quite evident that most recent research studies focused on big data analytics, IoT-based communication (Application of vehicle to another entity V2X…).

To answer RQ2: “What challenges have been reported for ITS applications in urban area context?” we identified 23 challenges grouped into six categories, summarized in Table 9 The challenge categories that received the most mentions were: 1) Cybersecurity & Privacy information (mentioned by 44% of the cases), 2) Coordination & collaboration among different Stakeholders (40%), 3) Different approaches emerge in a multi-actors environment (32%), 4) New ITS solutions requireless hardware, more software (28%), 5-6) The complexity of ITS Projects (24%) andthe lack of investment (20%).

Table-8. ITS R&D studies.

ITS Subsystems	Ref	Key technologies / results the studies focus on	Relevance
Advanced Traffic Management Systems (ATMS)	[1], [23], [24], [20], [25], [32], [33], [34], [35], [36], [38], [39], [40], [41], [42]	- Automatic incident detection on arterial roads - Proposed a relatively simplistic clustering technique in mobile phone for vehicle count, density, speed. - Seven multi-sensor data fusion-based estimation techniques - Studying a system to achieve automated driving on expressways - Expanding the use of ETC and other ITS technologies - Develop an automatic closed-loop algorithm to determine critical parameters. - Big data applications in real-time traffic operation - Vehicular Ad Hoc Network (VANET) - CMS (changeable message signs) - Agent and multiagent systems	2, 2, 2, 3, 2, 2, 3, 3, 4, 3, 3, 2, 3, 3, 3
Advanced Public Transportation Systems (APTS)	[5], [35], [37], [38], [42], [43]	- Bus Rapid Transit (BRT) - UHF RFID technologies for real-time passenger recognition	2, 3, 2, 3, 3, 2
Advanced Traveller Information Systems (ATIS)	[23], [24], [30], [31], [37],	- Generic and multimodal ITS framework - Generic multimodal transport network model for ATIS applications - GIS - based automatic transit traveler information system (ATTIS)	2, 2, 3, 2, 2
Commercial Vehicle Operations (CVO)	[26], [27], [28], [34], [40]	- RFID technology for order-picking operations - Research-Based decision-support software suggest for ultimate performance of Freight ITS - Automated transfer management system (ATMS) at terminal and distribution centers - Onboard safety monitoring (OBSM) system - Vehicle pre-clearance programs	3, 2, 2, 2, 2
Transit Management Systems (TMS)	[25], [32], [43], [58]	- Evaluation index system - Automatic vehicle location (AVL) and Automatic passenger count (APC) systems - Travel assistance device (TAD)	2, 2, 3, 2
Advanced Vehicle Control Systems (AVCS)	[26], [33], [42]	- Pneumatic road tube inductive loop detectors, piezoelectric sensors, magnetic sensors, and weigh in motion (WIM) - Video image processor, microwave radar infrared sensors, ultrasonic sensors, and passive acoustic array sensors. - Intelligent shared electric vehicle system - Innovated techniques for trip registration, intelligent monitoring, and vehicle communication.	3, 3, 2
Emergency Management Systems (EMS)	[29], [32], [36]	- Multi-commodity stochastic humanitarian inventory management model (MC-SHIC) - The emergency training prototype - Optimal model for the transportation of emergency resource - Advanced MMUI systems for emergency management	2, 3, 2
Incident Management Systems (IMS)	[1], [39]	- CIMS efficiency model - Perceptual Control Architecture of CPSs - FIAS - Freeway Incident Analysis System - Cooperative Awareness Messages (CAMs) - Decentralized Environmental Notification Messages (DENMs)	2, 3

Table-9. ITS applications challenges.

Challenge Group	Ref	Case	# of cases
Cybersecurity & Privacy information (44%)			
Skepticism towards the new technologies	[10], [11], [16], [47], [49], [50], [20], [17] , [4], [3], [56]	C2, C3, C4, C6, C8	5
Users unwiling to change			
Lack of confidence or reluctance shown by citizens (lack of clarity around benefits).			
Coordination & collaboration among different Stakeholders & technologies (40%)			
Interfacing between stakeholders & technologies difficult (Multi-agency, multi-modal, multi-purpose)	[2], [13], [19], [44], [18], [45], [51], [53], [56], [20]	C1, C3, C4, C5, C10	5
More people “in the control loop”			
Lack of political will			
Different approaches emerge in a multi-actors environment (32%)			
Keeping the old bureaucracy	[12], [13], [18], [19], [7], [52], [17], [53]	C3, C4, C6	3
Interpretation of ITS differs between stakholders			
Using old and new methods side by side			
Less hardware, more software (28%)			
SW development difficult to manage	[12], [44], [19], [54], [55], [56], [20]	C7, C8	2
Expensive skill marketplace			
SW requires a lot of maintenance			
Ever-changing security threats			
ITS Projects are complex (24%)			
Limited coverage	[2], [19], [46], [48], [20], [18]	C3, C10	2
Lack of information about existing & new ITS applications and initiatives			
ITS Technology readiness and maturity			
ITS Customized poorly			
Reverting to the old way of working			
The adaptation of ITS for urban area growth			
Lack of investment (20%)			
High cost	[2], [10], [18], [56], [4]	C3, C9	2
Lack of training			
Challenges in rearranging public spaces			
Old commitments kept			

These results show that ITS appears to be more difficult to implement in urban areas than people expect because of the different challenges... If these challenges are not carefully aligned and studied, this could lead to serious limitations for ITS deployment and, therefore, the full potential of ITS technologies cannot be achieved.

These challenges are evolving and vary from one ITS subsystem to another based on the prerequisite of deployment, and also, from one region to another based on the citizens culture. Therefore, according to our scope, the result show that ITS cannot be just taken into use off-the-shelf but must be carefully customized to fit well with the characteristics of the urban area and derive the best benefits from it. Although ITS is often seen as a grassroots movement from development, it is clear that management support is needed to achieve urban transformation. Mind-set and alignment have also increased, emphasizing that understanding the purpose behind ITS deployment, practices are important and aligning all stakeholders towards common purposes facilitates the transition to the smart cities.

There are no literature studies similar to ours on ITS, nor are there any specific surveys of ITS applications in urban areas. Existing studies and surveys have examined ITS in general, and not specifically the challenges of its adoption in urban area, e.g. ZEAR, Aditi, et al., 2016 [57] providing an overview of ITS progress in general.

The survey on the state of ITS did not highlights all current challenges. One explanation for this might be that the survey probably had predefined response categories limiting responses to them, whereas our categories were derived from the data, and were therefore not limited to predefined options.

C. Divergences and open issues

The articles included in our review provided several valuable insights in the form of challenges and practices. However, in examining the challenges, we can notice some divergences, revealing those aspects of ITS deployment that would require further study to find out more.

Dealing with bad & old infrastructure. It is not clear how and when to completely drop it and its related practices. The literature mentions the challenges of maintaining the old working method, such as the use of "old and new infrastructure side by side", which indicates that the coexistence of two different working methods generate new problematics.

D. Limitations

Researchers' bias may have influenced the choice of primary studies and data extraction. The selection of primary studies may have been distorted by misinterpretation of the inclusion criteria. This risk was mitigated by the coordination of the two researchers in designing the inclusion criteria. When inclusion criteria were used later, abstract filtering was done by both researchers independently, and confusing cases were resolved through case-by-case discussions. In the full text filtering stage, the first researcher performed the initial screening by making the decision regarding unambiguous cases. For the less clear cases both researchers read the paper and made independent proposals for inclusion or exclusion decisions. In cases where they agreed, the paper was included or excluded on the basis of their joint agreement. Articles that were not yet clear were discussed and resolved by the two researchers together.

The second part of the research that could be affected by subjective bias was the obtaining of results by coding and analysis. Our tools to mitigate this threat were limited because the steps are particularly laborious. Due to resource constraints, the process could not be duplicated. We have tried to avoid subjective biases in the analysis by making the results as traceable as possible, by providing references to each claim presented in the results.

A notable problem in this systematic literature review was the limitations of Boolean keyword searches in on-line databases. A keyword search does not easily identify urban areas and empirical facets, and also the applications facet is difficult to capture with keywords. As a result, we did not include the urban and empirical facets in the keyword search, but rather manually reviewed all articles selected in the filtering phase to determine if the article contained empirical material. This added manual work but mitigated the threat.

For the ITS applications facet, we used a variety of synonyms as keywords, but a small risk remains that some studies discussing applications without using any of the keywords we used remain unidentified.

Based on our preliminary search, we found four relevant papers that were not found by our keyword search, and which we included in the study as primary sources. In addition, by browsing the references of the 143 articles selected for full-text filtering, we identified five other relevant articles that had not been matched by the keyword search and that we included as primary studies. By these means, we wanted to make sure to locate papers that the keyword search might have missed. The fact that it was possible to find additional papers outside the search result suggests that it is still possible that our keyword search also missed other papers. However, because we have made reasonable efforts to identify missed publications, we believe that the number of missed articles remains very limited and therefore does not have a significant impact on the results.

Only seven references presented a clearly focused experience report. For this reason, we considered that the results would be very biased and that many valuable studies would be left out if a strict quality assessment were part of the inclusion criteria. Therefore, we decided to include all experience reports, irrespective of perceived objectivity.

The tendency to publish only positive results is also another particular limitation of this literature review. Studies generally indicated that the development and applications of ITS technologies were positive, indicating publication bias. A related problem is that most of the experience reports were written by people personally involved in the projects, so authors may be reluctant to

report implementation challenges. However, most of articles did bring up several challenges encountered during deployment as well as perceived practices. Given the current state of empirical research, it is necessary to include studies of varying weight of evidence in order to aggregate relevant evidence on urban applications.

Due to the authors and publication bias of the primary studies and the qualitative nature of the ITS application descriptions, we decided not to make quantitative interpretations in the results, but to use only qualitative analysis. Therefore, based on these data, we could not, for example, rank the challenges and say which are the most important. However, an examination of the number of cases cited gives an indication of the occurrence of factors in the existing literature. Nevertheless, because we do not know how well the published articles represent ITS applications, we cannot generalize the percentages to all urban area applications.

E. Future research agenda

Based on our literature review, we identify two topics that we think requires significant further study, and that together can be considered a research agenda on urban ITS applications.

a) Case studies on ITS applications

A larger number of experience reports with appropriate ITS technology in urban areas is absolutely necessary. In our review, we delineated the scope of ITS applications in the four selected developed countries. We were only able to identify seven experience reports on the subject. Although the topicality and importance for experts is confirmed, by the fact that in recent years, several books and courses have been published and organized by consultants, and a large number of conferences on this subject have been performed. Thus, the 49 research papers and the seven experience reports seem to only scratch the surface and report experiences from only a small portion of the actual number of development and applications projects. For this reason, we consider that more case studies must performed to gain more insights on ITS and how it is deployed in complex contexts.

b) Surveys on challenges and success factors

Surveys on challenges for ITS projects in general have been conducted in several developed countries. Our review was limited to selected subset regions (U.S.A, Japan and European Union) due to the large number of researches in this topic during the last decade. However, this indicates that there seems to exist a large number of countries that implemented or are in the process of implementation. It is therefore possible to carry out interesting survey studies. One topic for further surveys would be to explore how the challenges recognized in this study, are experienced in other countries: which ones they have experienced and which ones they consider most important.

Therefore, the actual situation of urban transportation in the developing countries is getting more difficult, migration of people from rural to urban areas has progressed quite differently compared to that of developed countries. Many areas have become urbanized without a significant increase in the quality of logistics infrastructure and without the development of new suburbs. Therefore, more works are needed to fill this gap, where there is a tremendous need for studies to understand the several challenges facing research and ITS adoption in these countries.

On the other hand, it would be important to study the success factors of ITS applications based on real experiences. As there are few ITS experience reports in the scientific literature, we encourage researchers to conduct deep case studies to understand how ITS is used and how it is customized.

6. CONCLUSIONS

We presented a systematic literature review of research and empirical studies on ITS applications in urban area. We reviewed 56 papers describing and presenting qualitative findings of ITS research and the challenges posed by ITS applications in urban area.

The primary studies identified were almost exclusively research papers, only seven experience reports were included. Thus, the main finding of this study is that despite the relevance of the topic for practitioners, real cases experiences report is significantly behind schedule, and consequently the identified challenges are those that practitioners perceive and report as most important. The relationship between elements and the objective facts remains unknown.

The challenge categories that received the most mentions impact in slowing up the development and implementation of new ITS solutions within urban area are: Cyber security & Privacy information, Coordination & collaboration among different Stakeholders, and those different approaches emerge in a multi-actors environment.

As future research topics, we suggest case studies and surveys on ITS applications challenges, studies on ITS deployment practices & success factors in developing countries.

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