Contextual Information in User information Systems in Public Transportation: A Systematic Review

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Abstract— **The accelerated urbanization rates have brought along an ever-increasing number of vehicles, which, in their turn, causes serious delays in people's daily travels. Users of public transportation, in particular bus passengers, have suffered the most, due to the lack of information about transportation means and traffic conditions. This creates anxiety and uncertainty about the travel, especially on metropolitan regions in developing countries. In this light, User Information Systems (UIS) aim to provide precise information, taking into account the context of the passenger and of the traffic. Hence, it is possible to better support users decisions and increase users' trust on the transportation means reliability. This work presents a systematic literature review, which aims to identify how (if at all) contextual information is used by Public Transportation User Information Systems.**

I. Introduction

Over the last few decades, traffic conditions, as well as all the disarray caused directly or indirectly by them, have become growing problems on every citizen's everyday life. The lack of punctuality and information about traffic as well as the poor conditions of available transportation means cause passengers a lot of difficulties to use these services.

In times where technology helps providing solutions to many problems, Intelligent Transportation Systems (ITS) are applied to aid in infrastructure and improve the quality of transport systems [3]. A particular category of ITS consists of the User Information Systems (UIS), intended to provide information to passengers (e.g.: waiting time at bus stops, vehicle current position, bus routes, and so forth). This information helps users trace their routes, better plan their travels and, in some cases, to know the current transit state [6].

In order to be effective, UIS must provide consistent transit information in real time. However, this can be quite difficult when the ITS is applied in a large city of a developing country, as observed by [5, 7]. Chaotic traffic, climate effects, accidents, poor road maintenance, all make it very difficult to foresee future traffic conditions, make time calculations or even present the user with a faster route to some destination, since the context involved in such operations is in constant change. Thus, it is necessary to develop intelligent infrastructure solutions that enable the capture and management of context information required to Intelligent Transportation Systems [1], without significantly hindering their performance.

This document presents the results obtained from a systematic review that aimed at mapping current research studies that use contextual information in User Information Systems for Intelligent Transportation Systems.

This work is organized as follows. Section II presents the concepts underlying systematic reviews, how they were applied and a description of the analysis protocol employed, Section III outlines the results of the analysis, Section IV summarizes and discusses the opportunities identified in this review. Finally, Section V presents our conclusions and opportunities for further work.

II. Method

A Systematic Review can be seen as the process of interpretation and assessment of available studies that are related to a research question or topic of interest [4]. Also, according to the same author, there are many reasons to conduct a systematic review, among which we highlight: synthetizing available studies about an approach or technology, identifying new research questions and helping steer the investigations towards unexplored or interesting areas within the topic of interest. In the following, we present how we have instantiated the 5 steps proposed by [4] in our Systematic Review about Intelligent Public Transportation Systems.

A. Research Questions

In order to highlight and investigate the use of contextual information by User Information Systems for public transport by bus, the following research questions were proposed:

- (RQ1) What contextual information is used by information systems for public transport users?
- (RQ2) How contextual information used by information systems for public transport users is acquired?
- (RQ3) How information systems for public transportation users use this contextual information?

B. Research Strategy

The literature search was conducted in two stages. The first step consisted of performing a manual search in Conferences, Workshops and Journals, aiming to capture full articles focusing on information systems for public transport users by bus with contextual data and written in English or Portuguese. The Conferences, Workshops and Journals selected are presented in Table I.

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TABLE I.

CONFERENCES, WORKSHOPS AND JOURNALS SELECTED

Type	Source	Acronym
Conference	Brazilian Congress on Transportation and Traffic	-
Conference	Symposium on road surface characteristics	SURF
Conference	World Congress and Exhibition on Intelligent Transport Systems and Services	-
Conference	World Congress on ITS Intelligent Transport Systems	-
Conference	Intelligent Vehicles Symposium	IV
Conference	International Conference on Vehicular Electronics and Safety	ICVES
Conference	Conference on Intelligent Transportation Systems	ITSC
Conference	Agents in Traffic and Transportation	ATT
Workshop	Workshop on Artificial Transportation Systems and Simulation	ATSS
Workshop	Workshop on Intelligent Transport Systems	ETSI ITS
Workshop	International Workshop on Intelligent Transportation Systems and Applications	ITSA
Journal	Communications of the ACM	CACM
Journal	IEEE Transactions on Software Engineering	TSE
Journal	IEEE Software	IEEESW
Journal	Journal of the Brazilian Computer Society	JBCS

In the second stage, the search was automated through a search string made up of keywords from each category presented in Table II, combined through the use of the Boolean operators "OR" and "AND". The strings were used to automatically search the following databases:

- IEEE Xplore
- ACM Digital Library
- EI Compendex
- ScienceDirect
- Scopus
- Brazilian Digital Computing Library (BDBComp[1])

The automated search strategy using search strings is widely used in systematic reviews and complements the manual search. This step has the objective to recover only the research studies that are relevant considering the research questions to be answered.

TABLE II

KEYWORDS USED ON SEARCH STRING CREATION

Category	Keywords
Intelligent Transportation Systems	intelligent transportation systems advanced public transport systems urban public transportation dynamic bus information systems user information systems
Transit	transit transportation bus urban dynamic users passenger trip planning information communication
Context	context-awareness context-aware awareness context-sensitive context location-aware

The search string was defined by the combination of the words on each category using Boolean operators "AND" and "OR", as shown below:

(("intelligent transportation systems" OR "advanced public transport systems" OR "urban public transportation" OR "dynamic bus information systems" OR "user information systems") AND ("transit" OR "transportation" OR "bus" OR "urban" OR "dynamic" OR "users" OR "passenger" OR "trip planning" OR "information" OR "communication") AND ("context-awareness" OR "context-aware" OR "awareness" OR "context-sensitive" OR "context" OR "location-aware"))

Due to the different functions and features of search engines, the search strings for the four digital libraries were similar but not the same. It is important to mention that all search strings were calibrated according to the requirements and characteristics of each search engine. Table III presents some specific search strings used on two of the digital libraries (e.g IEEE Xplore and ScienceDirect).

TABLE III

SEARCH STRING EXAMPLES

Engines	Search String
IEEE Xplore	(("Abstract":"intelligent transportation systems" OR "advanced public transport systems" OR "urban public transportation" OR "dynamic bus information systems" OR "user information systems") AND ("Abstract":"transit" OR "transportation" OR "bus" OR "urban" OR "dynamic" OR "users" OR "passenger" OR "trip planning" OR "information" OR "communication") AND ("Abstract":"context-awareness" OR "context-aware" OR "awareness" OR "context-sensitive" OR "Context" OR "location-aware")) OR (("Document Title":"intelligent transportation systems" OR "advanced public transport systems" OR "urban public transportation" OR "dynamic bus information systems" OR "user information systems") AND ("Document Title":"transit" OR "transportation" OR "bus" OR "urban" OR "dynamic" OR "users" OR "passenger" OR "trip planning" OR "information" OR "communication") AND ("Document Title":"context-awareness" OR "context-aware" OR "awareness" OR "context-sensitive" OR "Context" OR "location-aware"))
ScienceDirect	TaK(("intelligent transportation systems" OR "advanced public transport systems" OR "urban public transportation" OR "dynamic bus information systems" OR "user information systems") AND ("transit" OR "transportation" OR "bus" OR "urban" OR "dynamic" OR "users" OR "passenger" OR "trip planning" OR "information" OR "communication") AND ("context-awareness" OR "context-aware" OR "awareness" OR "context-sensitive" OR "context" OR "location-aware"))

[1] In Portuguese: *Biblioteca Digital Brasileira de Computação*

C. Criteria and Selection Procedures

After collecting the studies using the search strategy detailed in Section II, a relevance analysis for the research questions proposed on this systematic review was performed, classifying each study according to the following inclusion (I) and exclusion (E) criteria:

- (I) Academic only studies;
- (I) Public Bus Transportation Systems that operate with contextual information;
- (E) Public Bus Transportation Systems that do not operate with contextual information;
- (E) Duplicate work or not written in either English or Portuguese;
- (E) Intelligent Transportation Systems not targeted to public transportation by bus;
- (E) User Information Systems that do not use contextual data.

The steps used in this process were: (i) reading the titles and abstracts of the papers, noting the inclusion criteria and applying the exclusion, thus eliminating the studies that were irrelevant to the research questions under investigation; (ii) reading the introduction and conclusion of the studies selected in the previous step applying the same criteria; (iii) reading selected articles in the previous step in full, again applying the same criteria; (iv) selecting and documenting the remaining papers following a predetermined method, described in the following sections.

D. Quality Assessment

The quality of a study may constitute a criterion for inclusion, exclusion or supporting data analysis and synthesis [2]. In this systematic review, quality assessment was used mainly as a means of guiding the interpretation of results for the data analysis and synthesis in order to minimize errors when interpreting results. We chose to do so because our research questions pointed to a fairly recent area of research; thus, there were only a few relevant studies found (as pointed out in Tables V to VII. Consequently, we did not want to risk eliminating any potential studies prematurely.

This quality assessment did not qualify the studies with an overall quality score. Only criteria defined by [2] were used for classification in a binary scale. The criteria were:

a. Is the paper based on research or is it merely a "lessons learned" report based on expert opinion?

b. Is there a clear statement of the aims of the research?

c. Is there an adequate description of the context in which the research was carried out?

d. Was the recruitment strategy adequate with respect to the aims of the research?

e. Was the research design appropriate to address the aims of the research?

f. Was there a control group with which to compare treatments?

g. Was the data collected in a way that addressed the research issue?

h. Was the data analysis sufficiently rigorous?

i. Has the relationship between researcher and participants been adequately considered?

j. Is there a clear statement of findings?

k. Is the study of value for research or practice?

E. Data Extraction and Synthesis

A data extraction form was designed in order to gather the required information to address the objectives of this study, classifying and answering the research questions. Initially, the full paper was read and the following information was extracted from each study: author, title, source, year, volume, pages, summary, keywords, and whether or not they adhered to the inclusion criteria.

After the studies found had their information extracted, they were categorized according to what was proposed by [8]. The categories used were: (i) case study; (ii) experimental study; (iii) literature review; (iv) lessons learned and (v) simulation. An open-source tool called Mendeley[2] was used to manage these references.

Once all of the studies had been cataloged, we analyzed them both qualitatively and quantitatively. The results of such analyses allowed us to identify properties and characteristics related to answering the research questions posed in this review, as reported in sections III and IV.

III. RESULTS

This review was carried out over the course of five months, from July 2011 to November 2011, according to the procedure presented in Section II. After performing the steps described in Section II A, II B and II C, a total of 10 studies were selected, as shown in Figure 1.

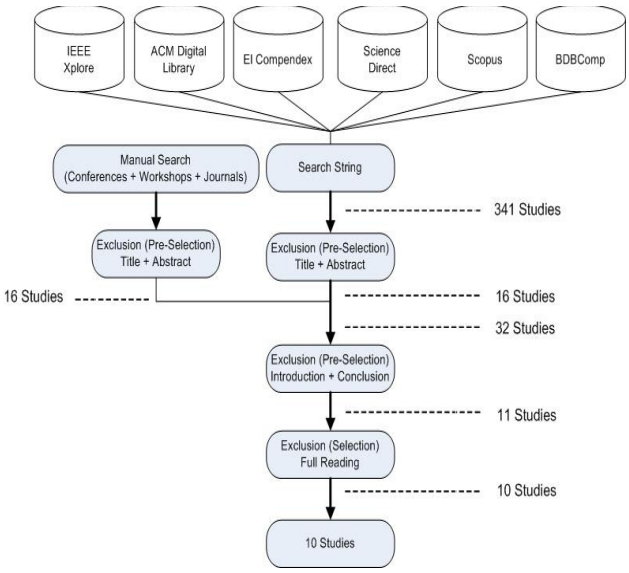

Figure 1. Research Studies Filtering Process

Furthermore, the automated search on engines from research studies repositories resulted in a total of 341 studies. After performing a pre-selection amongst those, done by

[2] http://www.mendeley.com/

reading their titles and abstracts, and a manual filtering with the same criteria, 32 studies were selected. Performing pre-selection by reading the introduction and conclusion, 11 articles were selected; and finally, after the full reading step was completed, 10 studies were selected for analysis.

The 10 studies selected for this review are presented in the Further Reading section, with numbers preceded by SS (Selected Studies) to distinguish them from the reference numbering. Table IV presents the application of the 11 criteria chosen for assessing the quality of study, with the symbols (✓) indicating "yes" and (×) indicating "no". The list of criteria is described in Section II D.

TABLE IV. QUALITATIVE ASSESSMENT

Ref.	a	b	c	d	e	f	g	h	i	j	k
[SS 01]	×	✓	✓	✓	×	×	×	×	×	✓	×
[SS 02]	✓	✓	✓	×	✓	×	✓	×	×	✓	✓
[SS 03]	✓	✓	✓	✓	×	×	✓	✓	×	✓	✓
[SS 04]	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓
[SS 05]	✓	✓	✓	✓	✓	×	✓	×	×	✓	✓
[SS 06]	✓	✓	✓	✓	×	×	✓	✓	×	✓	✓
[SS 07]	✓	✓	✓	✓	×	×	✓	✓	×	✓	✓
[SS 08]	✓	✓	×	×	×	×	✓	×	✓	×	✓
[SS 09]	✓	✓	✓	✓	×	×	✓	×	✓	✓	✓
[SS 10]	×	✓	✓	×	×	×	✓	×	×	✓	✓

More details about the selected studies can be found on the next section in this document.

IV. DISCUSSION

This section analyzes and discusses the contents and characteristics of the 10 studies selected in this systematic review. This analysis was done to extract relevant information and answer the questions proposed in Section II A.

(RQ1) - What contextual information is used by information systems for public transport users?

The accessibility to information about public transport in a particular city or region can make this type of transport more attractive to passengers (e.g.: location of buses) [SS 09]. Through this information users can plan their trips and ease their anxiety when waiting for transport [SS 03].

Taking into consideration this scenario and since transit is liable to rapid changes, caused by many different situations that may occur (e.g.: traffic jams, accidents, floods, etc.), understanding the context of buses, routes, passengers and other devices is an essential factor to support User Information Systems [SS 04] [SS 09].

Static information stored in databases and data and dynamics that characterize the current state of transit (e.g.: historical data, weather conditions, geographical data in real time, etc.) can be used to enrich the information provided to users.

Analyzing the 10 selected studies, we realized that many use static contextual information (e.g. location of bus stops). Dynamic data are handled in a small scale, in most cases consisting of location data of vehicles, as shown in Table V.

TABLE V.

CONTEXTUAL INFORMATION HELD IN SELECTED STUDIES

Type of Contextual Information	Contextual Information	Studies	Freq.
Dynamic	Location of Vehicle	[SS 02], [SS 03], [SS 04], [SS 05], [SS 07], [SS 08], [SS 09], [SS 10]	8
	Speed of Vehicles	[SS 05], [SS 09]	2
	User's Feedback	[SS 06]	1
	Incidents in the Way	[SS 03]	1
	Traffic Intensity	[SS 09]	1
	User's Location	[SS 02], [SS 03]	2
Static	Location of Stops	[SS 01], [SS 02], [SS 03], [SS 04], [SS 05], [SS 06], [SS 07], [SS 09]	8
	Distance between stops	[SS 01], [SS 02], [SS 03], [SS 04], [SS 05], [SS 06], [SS 07], [SS 09]	8

(RQ2) - How contextual information used by information systems for public transport users are acquired?

Intelligent transportation systems usually work with large amounts of information. The acquisition of these often requires some care, since the data may require some kind of adjustment or pre-processing so that it can be safely used by User Information Systems [SS 07].

Information used in transportation systems are usually static, dynamic or implied. Static data acquisition can be performed using test vehicles [SS 07], catalog data, among others. Such information is stored in a database and usually do not undergo changes [SS 01].

Dynamic information requires checking before they are used by applications, in order to make sure they are correct. They typically undergo changes, making the applications more efficient [SS 09]. The inferred information are calculated by the system, based on other information already present (e.g.: user's history), adding more value to the application [SS 02].

With the increasing use of smartphones, User Information Systems are now adapting their processing to receive data from its users, either from their devices own GPS or from the integration of other relevant information.

Table VI presents how the selected studies in this review acquire contextual data.

(RQ3) – How public transportation user information systems use this contextual information?

User information systems aim to facilitate the daily life of people using public transport, providing information to passengers often in real time, based on static data, inferred or dynamic context related to the transportation [SS 02] [SS 09].

The application found in the literature meet the needs of users, either specific (e.g.: waiting time in stop until next suitable bus arrives) or personalized (e.g.: routing of bus lines) [SS 01].

TABLE VI.

ACQUISITION OF CONTEXTUAL INFORMATION IN SELECTED STUDIES

Acquisition of Contextual Information	Studies	Frequency
GPS equipment located on the Bus	[SS 04], [SS 05], [SS 07], [SS 08], [SS 09], [SS 10]	6
User's FeedBack by smartphone	[SS 06]	1
GPS User's	[SS 02]	1
Historical Information	[SS 05]	1
Inferred Information by Application	[SS 09]	1
Historical Information Previously cataloged	[SS 01], [SS 02], [SS 03], [SS 04], [SS 06], [SS 07], [SS 08], [SS 09], [SS 10]	9
Not discussed	[SS 03]	1

Electronic equipment are an important factor in the objectives proposed by the User Information Systems, because when installed on the vehicle, such equipment assist by warning about nearby stops (e.g.: bus stops), taking this responsibility off the driver, allowing them to remain focused only on driving. Equipment installed on the roadways can inform schedules, travel time, waiting time and bus itineraries, reducing passengers' anxiety [SS 04] [SS 10].

However, installing electronic equipment in all the stops and inside vehicles can be quite expensive and impractical. With the increased use of mobile devices, the information provided by the UIS can be displayed on them. Moreover, the devices can provide their current location, making them a great advantage for user information systems, since user location is an important contextual information that can be used to improve personalized route recommendations, for example. [SS 02] [SS 05].

Table VII presents how the selected studies in this review use the information collected to provide contextual information to users.

TABLE VII.

INFORMATION PROVIDED TO USERS THROUGH CONTEXTUAL INFORMATION

Information provided	Studies	Frequency
Vehicle Arrival Time on the Stops	[SS 03], [SS 04], [SS 05], [SS 06], [SS 07], [SS 08], [SS 09], [SS 10]	8
Display of bus route	[SS 01], [SS 06]	2
Personalized Route Creation	[SS 02], [SS 05]	2
Indication Route	[SS 02], [SS 05]	2
Notification of Next destinations	[SS 05]	1
Quality of Traffic	[SS 05]	1
Custom information to users	[SS 03]	1
Location of Bus	[SS 06], [SS 07]	2

Analyzing the results presented by the questions posed in this systematic review we notice the following:

1 - Many of the selected research studies use static data and dynamic bus location information, albeit in a very small scale. The use of other dynamic information (e.g.: incidents on the roads, collaborative information from other users, among others) could provide users with information more in line with the current situation of transit, considering the dynamic characteristics of urban traffic, especially in large cities.

2 - Regarding the acquisition of information by the UIS, we notice that many of the selected research studies capture these data either through GPS installed in the vehicles, or statically through information cataloging. However, other sources of acquisition could be better used (e.g.: social networks, cameras, sensors and other).

3 – With respect to the information offered to users, we have noticed that the majority of applications offers passengers the calculation of the arrival time of vehicles in the stops, and while some offer user-adapted functionality (e.g.: better bus routes recommendation, and other personalized user services) [SS 02] [SS 05].

V. CONCLUSION

Currently, Intelligent Transportation Systems have become a very viable and attractive alternative to solve many problems and overcome challenges in large cities transit systems. This trend is partly due to the rapid growth and availability of Information and Communication Technologies.

The increasing amount of available information also entails a demand for systems that provide information relevant for their users, according to the situation they find themselves in. In other words, dynamic, context-sensitive systems are becoming increasingly popular. The use of such applications to provide information for public transport users can provide great attraction and loyalty to the system.

This article presented a systematic review regarding the use of contextual information in the information systems to users of public bus transport. A systematic review aims to evaluate and interpret all available research related to a research question or topic of interest through a rigorous and reliable methodology [4].

The results were presented in two phases: the first phase, quantitative data were shown, including the number of studies of phase selection and search sources, in the second phase, the selected studies were qualitatively evaluated (Table IV), synthesized, and some characteristics of the state of art discussed, according to research issues.

As a result of this work, we can identify the following research opportunities, detailed below:

1 – Development of User Information Systems that make use of a larger amount of both dynamic and inferred contextual information, since this information can help the application deal with the dynamic character of transit in a better way, allowing it to provide information with greater quality i.e. more adequate to the current reality of urban traffic.

2 – Use of new sources of contextual data that can provide real time information to support User Information Systems. With the increasing use of social networks, these could be used as sources for collaborative user information.

3 – Exploration of the use of mobile applications, taking advantage of the growing use of smartphones among users.

4 – Development of new features tailored to users, seeking to provide personalized services, more relevant to users' needs.

5 – Analysis of the relationships between contextual information in order to enrich the functionalities provided by User Information Systems.

In our research project, entitled UbiBus [7], we investigate the use of technologies related to mobile devices, web and social media to support public transport passengers in large and medium urban centers. Part of the future work on the project will be dedicated to developing solutions that aim to fill the gaps found as a result of this systematic review.

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