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Architectures and Applications of Intelligent Transport Systems: A Review

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Abstract: *The aim of this article is to analyze applications and developments presented within the last 7 years associated to intelligent transport systems, as well as the most outstanding architectures at global level and their general components. The review of the literature enabled to identify those investigations with the greatest impact within the last 5 years, as well as the action fields most explored within this type of systems. In the same way, the most representative architectures at global level were analyzed, allowing to recognize those features which make themselves a model for other countries. Additionally, a standard design applicable to any country eager to implement a transport system like these was identified.*

Keywords: *Architecture, artificial intelligence, intelligent transport system, traffic safety.*

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I. Introduction

Intelligent transport Systems - ITS refer to a scientific and engineering discipline, which aim is to minimize the passengers transit time and the commodities placed in vehicles, ensuring the safety and perfect integration of the different transport modes, including vehicle traffic. In addition, they allow the use of transport networks in a more secure way than the conventional one, through the implementation of artificial intelligence.

The development of modules and applications involving the implementation of computing and technology has been one of the greatest interests of researchers in recent years, providing solutions to problems associated with traffic and transport. Nevertheless, there are no studies analyzing the applications and architectures designed at global level associated to these systems jointly, which lately triggers the necessity for this research development. Initially, the study of the research with the greatest impact in recent years is established, as well as a classification of the most representative focus areas. Likewise, the globally designed architectures in 3 countries and a standard one are analyzed, using established using generic parameters required for this kind of systems.

II. Intelligent Transport Systems

Transport refers to: "The movement of the product from one place to another in its journey from the beginning of the supply chain to the customer" (Chopra & Meidndl, 2008). An additional definition refers to a "Set of actions that are constantly repeated, which aims to change position with respect to the space of people and / or things, whose utility is greater elsewhere" (Islas & Zaragoza, 2007).

In a generic way, an adequate management in the transport systems must guarantee the presence of attributes that altogether allow providing an adequate service, which are detailed in Table 1. In relation to the ITS, it is known that they began with the development of Intelligent Vehicle Highway Systems - IVHS. However, thanks to researchers Kan Chen and Bob Ervin, an extension of this subject is later established, commonly known as ITS. These refer to a scientific and engineering discipline, which objective is minimizing the transit time of passengers and the goods placed in the vehicles, guaranteeing the safety and perfect integration of the different transport modes, including the vehicle traffic. In addition, they allow to know the exact status of the vehicle from any point within the system and calculate the most efficient route. (Ghosh & Lee, 2010) & (Dong & Paty, 2011)

The key to successful solutions for complex transport problems comes from a global understanding of the control and coordination algorithms. In this way, it provides relevant and accurate information in a timely manner, allowing the creation of decision alternatives. The main features of an ITS are its ability to provide accurate information (accurate and updated) and ensure control, coordination and management of available resources. In relation to the transmission of information, it is considered that it comes in large volumes, so it must be done economically and reliably. In the same way, it must be used properly and in real time, guaranteeing greater efficiency in operations. (Ghosh & Lee, 2000) & (Sussman, 2005).

Table 1. Attributes of transport systems. Adapted from (Islas & Lelis, 2018)

Attribute	**Description**
Speed	Time used to go from one point to another, considering the mode of transport and the conditions in which it operates.
Capacity	Number of users that can be served.
Security	Probability of generating damage to property, people transported or third parties.
Frequency	Number of vehicles that are presented at a given point to satisfy a demand in a certain time interval.
Regularity	Measurement of compliance with the determined time intervals.
Accessibility	Set of activities or procedures prior to mobilization.
Simplicity	Provision of service with a minimum number of movements.
Responsibility	Response issued by the system in case of failure or damage.
Coverage	Areas ? that benefit from the service.
Flexibility	System capacity to adapt to changes in operating requirements.
Cost	Total resources consumed in the provision of the service.

ITS are currently sorted out into five areas:

- Advanced Traffic Management Systems - ATMS. - Identify real-time situations of traffic conditions to be sent to the control center.
- Advanced Traveler Information System- ATIS. - Users can access information on the status of the roads, which allows them to analyze the means of transport, as well as the routes to be selected.
- Commercial Vehicle Operations - CVO. - It allows to improve the efficiency and security of the service provided, through the automatic control of vehicles and efficient management of the fleet.
- Advanced Vehicle Control and Safety Systems- AVCSS. - Increase traffic safety and reduce accidents, providing support for vehicle control.
- Advanced Public Transportation Systems - APTS. - Increase the quality and efficiency of the service, through the implementation of the ATMS, ATIS and AVCSS technologies. (Telecommunications Research Center - CINTEL, 2010) & (Gordon, 2009)

The main functions of the ITS are travel and transport management, travel demand management, public transport operation, electronic payment, commercial vehicle operation, emergency management and advanced vehicle control and security systems. Despite this, in eleven years, eleven categories have been studied, which obey traffic signal control, traffic management and surveillance, incident management, electronic toll collection, driver behavior, traveler information, intelligent parking management, public transport management, commercial vehicle management, vehicle control technologies and mobility sharing. Each of these are characterized as follows:

- Control of traffic signals: They allow to manage the traffic speed. Through the microsimulation systems, it is possible to evaluate impacts from different emissions of traffic signals, travel time and fuel consumption.
- Traffic management and surveillance: Includes incident management, measurement ramp; which allows to establish the level of security of a vehicle when entering the traffic of a road and traffic surveillance.
- Incident management: It is carried out through timely communication to drivers, by sending signals to mobile devices, reducing congestion caused by an incident, allowing to establish alternative routes.
- Electronic toll collection: Electronic antennas are used, which identify the vehicle's label, usually located on your windshield. In other modalities, making use of fixed cameras, the plate number is stored for the subsequent collection.
- Driver behavior: Allows the driver to know how its driving affects performance, as well as fuel consumption.
- Information for travelers: Provides real-time information for managers and public, guaranteeing routes selection ,suitable travel modes and estimated time, according to these variables.
- Intelligent parking management: They support the improvement in payment methods for parking lots, timely reservation and the cost for the service.
- Public transport management: It supports the improvement in the service provisioning, through the automatic vehicle location, signaling and arrival time.
- Commercial vehicles management: Includes automatic location of vehicles, weighing when these are in motion.
- Vehicle control technologies: Aimed to increase the safety levels, efficiency,vehicle comfort and performance indicators.

- Mobility sharing: It Refers the interaction of a vehicle fleet, with other types which share the road with, such as motorcycles and individuals.

(Shaheen & Finson, 2013) & (Cheng, Gau, Huang, & Hwang, 2012)

III. Methodology

The approach of the proposed research is qualitative, considering the analysis of applications developed within the last 7 years in ITS, plus different representative architectures. In addition, the scope exploratory, considering that a detailed search was made of previous investigations in this type of systems and those architectures that are a reference and / or standard for other countries. Previous investigations were developed between 2011 and 2018. The above, making searches in databases such as Scopus, ScienceDirect, ProQuest, Dialnet and Web of Science and specialized books for the established topics. Once authors with the highest level of incidence in subsequent investigations were identified, an analysis of the evolution presented in the ITS was done. In relation to the identified architectures as those with the highest level of impact at global scope, their components were determined to identify generic action axes.

IV. Analysis Of Applications And Architectures In Its

During the last 6 years, 583 research projects associated with ITS worldwide were done, demonstrating a significant increase between 2013 and 2018 in approximately 51 %. During this interval, we have determined the top 10 works with the highest citation index in this topic, as it can be seen in Table 2. Authors, journal and year of publication, total citations and average number of citations.

The work with the highest level of influence is associated with the traffic forecast, presenting 101 citations in total; which represents an average of 25.25 citations per year. Similarly, it is possible to prove that 8 out of the 10 publications belong to the IEEE Transactions on Intelligent Transportation Systems journal, which is specialist in the analysis of this type of systems.

Table 2 Research on ITS with the highest level of citation within the last 5 years. Adapted from (Clarivate Analytics, 2018)

Title	**Authors**	**Journal**	**Publication year**	**Total citation**	**Average per year**
Short-term traffic forecasting: Where we are and where we're going	Vlahogianni, Eleni I.; Karlaftis, Matthew G.; Golias, John C.	Transportation Research Part C-Emerging Technologies	2014	101	25,25
Development and Evaluation of a Cooperative Vehicle Intersection Control Algorithm Under the Connected Vehicles Environment	Lee, Joyoung; Park, Byungkyu	IEEE Transactions on Intelligent Transportation Systems	2012	92	15,33
Cooperative Adaptive Cruise Control in Real Traffic Situations	Milanes, Vicente; Shladover, Steven E.; Spring, John; Nowakowski, Christopher; Kawazoe, Hiroshi; Nakamura, Masahide	IEEE Transactions on Intelligent Transportation Systems	2014	80	20,00
Traffic Flow Prediction with Big Data: A Deep Learning Approach	Lv, Yisheng; Duan, Yanjie; Kang, Wenwen; Li, Zhengxi; Wang, Fei-Yue	IEEE Transactions on Intelligent Transportation Systems	2015	74	24,67
Short-Term Traffic Flow Forecasting: An Experimental Comparison of Time-Series Analysis and Supervised Learning	Lippi, Marco; Bertini, Matteo; Frasconi, Paolo	IEEE Transactions on Intelligent Transportation Systems	2013	56	11,20

4.1 Applications

According to the studies analyzed, it is possible to identify different developments in information technology that efficiently support the implementation of ITS, which represent 55 % of the research presented.

Table 3. Applications of intelligent transport systems

Work	Area	Application
(Crainic, Gendreau, & Potvin, 2009)	Computing	Review of the main technological challenges, problems and achievements that have been presented in the implementation of intelligent transport systems.
(Jianwei, Zhenxiang, & Zhiheng, 2010)	Economics	Evaluation of profitability when implementing an intelligent transport system, as well as its viability in the Chinese environment.
(Dong & Paty, 2011)	Traffic management	Adaptation of a feedback strategy to an intelligent transport system, according to the flow of traffic presented.
(Chen, 2011)	Security	Design of an intelligent transport control system, using neural networks, with the purpose of increasing the safety and efficiency of the process.
(Cheng, Gau, Huang, & Hwang, 2012)	Traffic management	Development of a highly integrated intelligent transport system, based on multimedia analysis technology.
(Shah, Kumar, Bastani, & Yen, 2012)	Traffic management	Development of two optimization models, mixed whole programming and space-time flow network, applied to the intelligent transport system.
(Lo, 2012)	Traffic management	Design of a multi-agent information transmission mechanism that allows efficient real-time decision making.
(Román, Madinabeitia, Jiménez, Molina, & Ternero, 2013)	Computing	Design and development of an architecture of an intelligent transport system, based on a reference model, which facilitates scalability and interoperability.
(Satunin & Babkin, 2014)	Economic	Development of a new approach for the design of transport demand response systems, under the multi-agent scenario, that is, when the intervention of several actors is presented.
(Hung, Wang, & Yan, 2014)	Computing	Design of a data exchange platform in an intelligent transport system, allowing the reception of several types of input data.
(Pan , Wang, & Yan, 2014)	Computing	Design of a data exchange platform in an intelligent transport system between external and internal equipment of vehicles.
(Gosman, Cornea, Dobre, Pop, & Castiglione, 2016)	Computing	Design of an information security model for users of an intelligent transport system, according to their privacy requirements.
(Gregor, and others, 2016)	Computing	Design a systematic methodology that allows retrieving information in intelligent transport systems, allowing the connection of new equipment to an urban network.
(Wang, Li, Zhou, Wang, & Nedjah, 2016)	Computing	Design of the NeverStop tool, which uses genetic algorithms and fuzzy control methods in intelligent transport systems, specifically in the management of traffic lights.
(Janušová & Čičmancová, 2016)	Security	Analysis of intelligent transport systems that can be implemented to ensure the safety of road and rail infrastructure.
(Bommes, Fazekas, Volkenhoff, & Oeser, 2016)	Computing	Structured review of current and future applications of image processing techniques in intelligent transport systems.
(Sun, Li, & Gao, 2016)	Computing	Description of the architecture of an intelligent cooperative transport system, from the perspective of the stakeholders and five main approaches: business, functionality, connectivity, communications and information.
(Sousa, and others, 2017)	Computing	Design of a vehicular adhesion network architecture, guaranteeing the use of several communication technologies applied to intelligent transport systems.
(Korjagin & Klachek, 2017)	Traffic management	Support for the creation of a biokinetic management system, based on the use of unmanned vehicles that guarantee traffic safety, so that it can be implemented in intelligent transport systems.
(Petrov, Dado, & Ambrosch, 2017)	Computing	Design of a vehicle-to-vehicle and vehicle-to-infrastructure communications model, in accordance with the current and future capabilities of communication technologies.

Additionally, it is determined thje existing concern associated to traffic management, which allows the reduction of the vechicles travel time, evidencing 25 % of the total of investigations. 20 % of these correspond to economic and safety analysis in the development and implementation of ITS.

4.2 Architectures in ITS:

The International Organization for Standardization - ISO, has established an architecture for the ITS, in such a way that its activities are standardized. However, its structure is simple, so it has only represented a starting point to establish other systems. This structure is duly registered in ISO 14813-1: 2007. - Intelligent Transport System, Reference model architecture for the ITS sector. In this standard, it is possible to identify a reference model established as a UML (Unified Modeling Language) diagram, as can be seen in Figure 2. It is possible to identify 11 groups of services related to: traveler information, traffic management and operations, vehicles, cargo transport, public transport, emergencies, electronic payment of transport services, passenger safety in road transport, monitoring of weather and environmental conditions, management and coordination in response to disasters and national security. Despite the establishment of this regulation by the ISO, the first standard architecture for ITS was developed in the United States during the early 90's. This design is presented in Figure 3. In this, it is possible to identify a set of user services with their associated requirements, a logical architecture as well a physical one. Similarly, 33 user services are condensed into 8 categories: travel and traffic management, public transport management, electronic payment, commercial vehicle operations, emergency management, advanced vehicle safety systems, information management and maintenance and construction management.

It is necessary to emphasize that states and metropolitan areas must adhere to the considerations established within the national architecture, in such a way that they are adapted to the regional requirements.

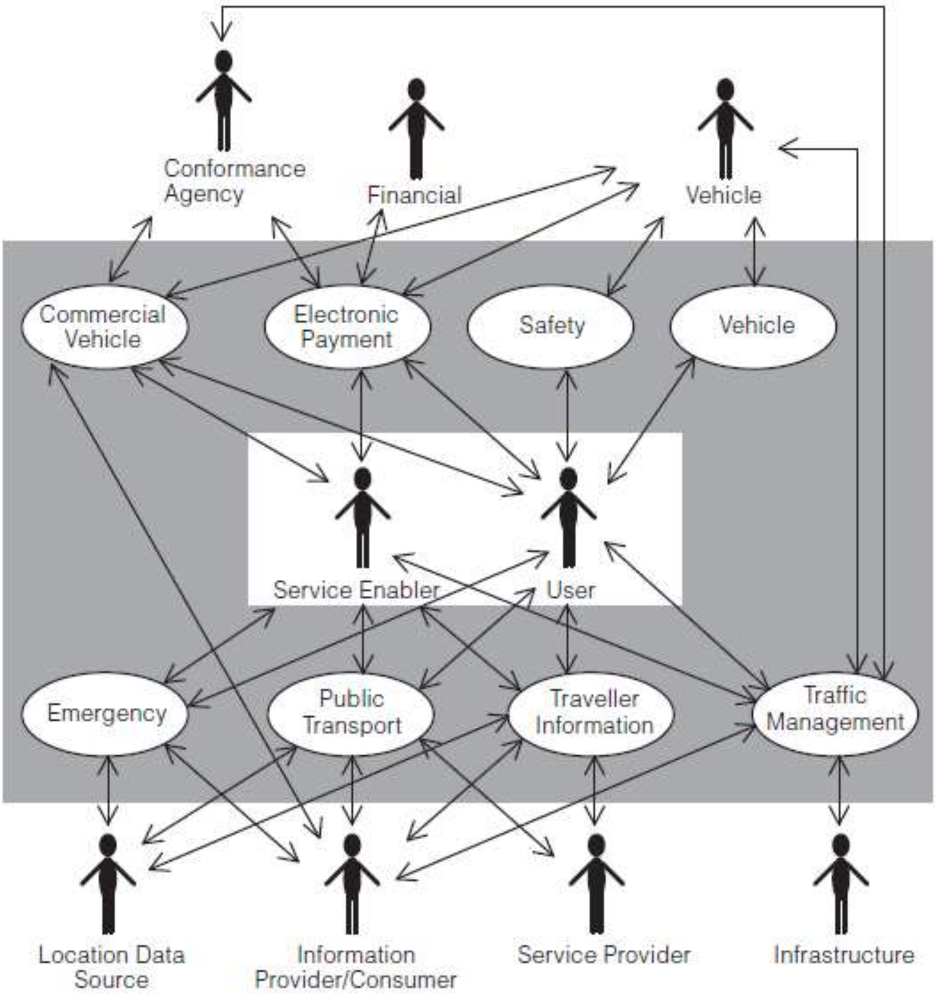

Figure 2. Reference model for the architecture of an ITS (Yokota & Weiland, 2017)

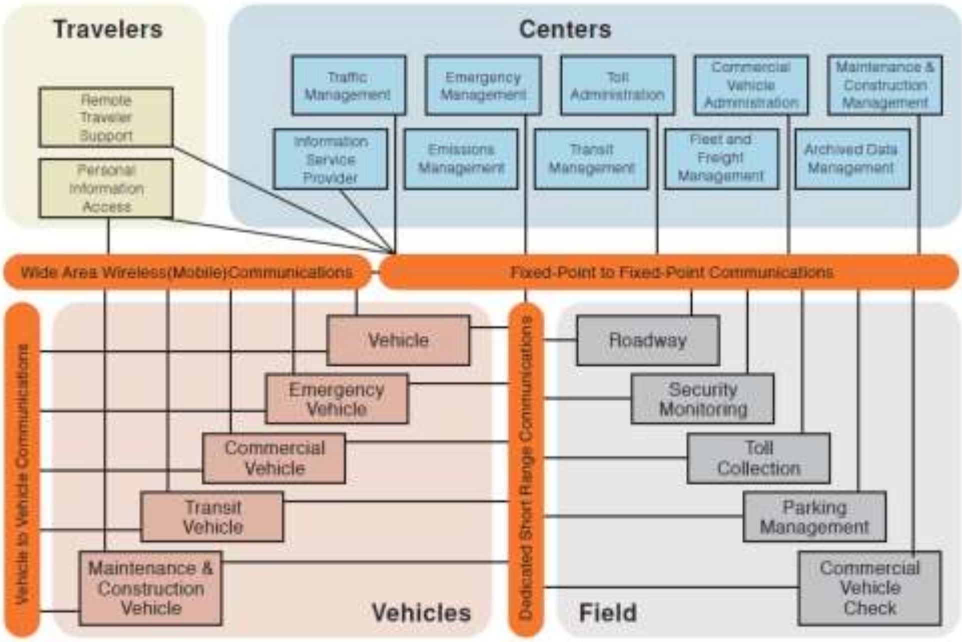

Figure 3. National architecture of the United States for ITS (Yokota & Weiland, 2017)

At the end of the 1990s, Japan developed its own architecture based on two goals namely, guaranteeing the level of flexibility required to adjust to changing society, technology and interoperability with other development edges such as telecommunications. In the same way it was evidenced in the American architecture, it is possible to validate a logical and physical component in the Japanese one, as shown in figure 4. The development areas considered for this case are: advances in navigation systems, payment systems electronic tolls, assistance for safe driving, optimization of traffic management, increased efficiency in road management, support for public transport, increased efficiency in commercial vehicle operations, support for pedestrians, support in the operation of emergency vehicles and finally a generic component that allows the use of telecommunications in society.

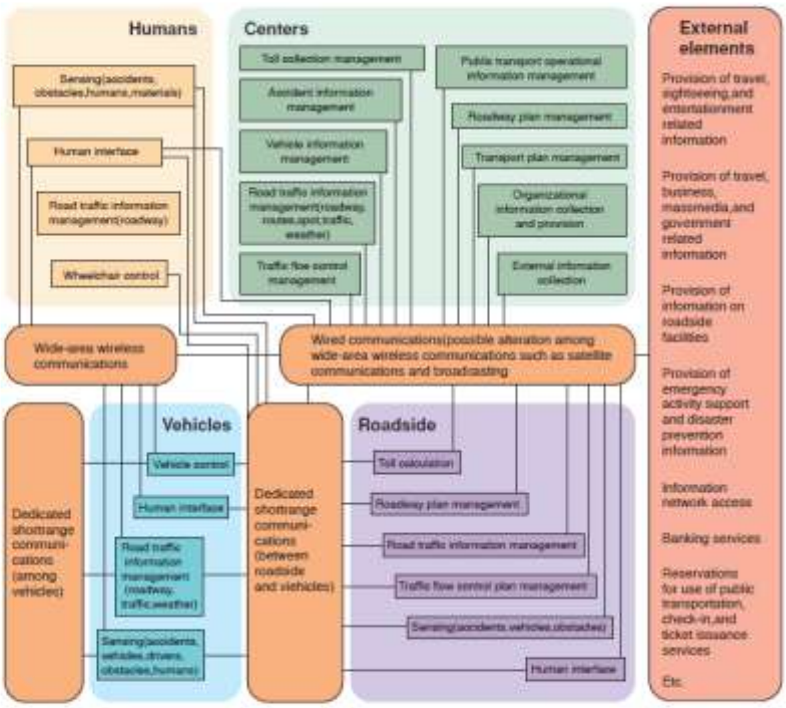

Figure 4. Japan's national architecture for ITS (Yokota & Weiland, 2017)

Finally, the established architecture for Colombia is shown, considering that it is the country of interest by the Author for future researches and an adaptation from other architectures of great recognition such as the American one has been created. This arises in 2010 by the company ConSysTec. 22 main actors and 4 generic components were identified inside it. In a complementary way, each of these components was characterized with the subsystems that ensure its efficient operation; plus, regarding to the terminators that intervene in fixed point communications, that correspond to:

- Trade regulatory agencies
- Care center
- Vehicle registration department
- Railway rail equipment
- Ease of storage
- Ease of repair of vehicles
- Inspection
- Financial institution
- Railway operations
- Press
- Event promoters
- Electronic map provider
- Multimodal public transport service provider
- User data file system
- Electronic travel card

V. Conclusions

ITS have been implemented as a strategy to reduce transit time for each route, so they have been considered as support in large cities in need of mitigating problems associated to traffic. Within the last 5 years, a greater interest in the research of this type of systems has been observed, as well as applications that allow an increased level of efficiency of fields such as information technology, traffic management and security.

In the same way, different architectures have been developed such as the standardization presented by the ISO and the adaptations designed by the United States, Japan and Colombia; although the latter has not yet been implemented. In each of these it is possible to identify generic components associated to travelers, centers, vehicles and field; which represent a physical and logical architecture that supports ITS.

According to the researchers analyzed, there is a special interest to increase the efficiency of transport in relation to public and commercial services, so it is suggested for future studies to analyze the support of ITS to situations of human vulnerability, such as natural disasters or emergency situations.

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