Influence of Intelligent Transportation System in a Road Infrastructure

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ABSTRACT

Over the past 30 years, it has seen the development of Intelligent Transportation Systems - ITS around the world in different ways, designed to reach new transport patterns, and with it, the concept is gaining more credibility among users. With this technology, the goal is to establish communications between user, vehicle and infrastructure in an integrated manner and thus provide a supply of a more sustainable and efficient transport. This paper introduces the basic concepts of ITS, its Architecture, and shows the most recent studies in the area. Property use of this system can bring gains in sustainability, mobility and security, being a breakthrough for transport system.

Keywords: Intelligent Transportation Systems – ITS, Vehicle Speed Optimization, Connected Vehicles; Mobility; Transportation System.

1. INTRODUCTION

Any community requires mobility for its operation. The options for work, leisure and consumption, as well as access to education, health and information rely on the quality of the transportation system available.

Traditional solutions for managing transport systems have proved inefficient in the long term option [1]. Intelligent Transportation Systems - ITS emerges as a new way of working, as a basic principle communication and information exchange, to establish better rates of mobility, sustainability and security.

ITS involves everything related to information and technology. The gathered information can be provided both for the network controllers, and for end users [2]. A wide range of techniques and approaches can be achieved through independent technological applications or as enhancements to other transport strategies.

The applications for ITS are countless: new ways for managing intersections are now possible through the communication between vehicles and infrastructure (V2I), eliminating the use of traffic light [3]; Special vehicles like ambulance or police cars can have priority in traffic [4]; Anti-collision systems can prevent a car for running over a pedestrian [5]; Even the maintenance of pavements can be predicted through the collection of data from sensors installed in vehicles [6].

The successful development and application of this technology may be the key to solving many of the current transport problems such as traffic congestion, greenhouse gas emissions and also ensure prevention of accidents, providing more reliable and cost-effective solutions [7]. However, it is important to understand that ITS is not the solution for all transportation problems. In certain cases, conventional procedures are still the most suitable to be implemented [8].

This paper introduces the basic concepts of ITS, suggest the minimum infrastructure required and shows the most recent studies in the area.

2. BACKGROUND

What is a transportation system

A transportation system is a way that enables the offsets for the pleasure of personal or collective needs of a society. Transport influences most of social activities, which is reflected in the political, social and economic fields [9]. The development of an area is associated to the degree of its transportation system's sophistication.

The components of a transportation system represent all of its connections with the environment, as well as its internal relations.

Among the external and internal agents, include: the government (as the first promoter of the transportation system); the market (as evolution factor of the companies connected to the system, and the financial community in general); operators (including all forms of work related to the system and supply of the required infrastructure); and, finally, the user [7].

Current Situation of Transportation Systems in Brazil and in the World

In Brazil, traffic accidents are the second largest public health problem in the country, second only to malnutrition. In 2011, there were 45,000 deaths due to accidents [10]. Large economic losses are also caused by traffic accidents, both for the victims' families as for the nation as a whole. These costs often include medical treatments, burial's expenses and also the lost work time due to the disability caused by a serious injury.

From the global aspect, traffic statistics are also worrying. Traffic accidents are the eighth leading cause of death worldwide and the leading cause of deaths among drivers between 15 and 29 years. 1.24 million people are killed worldwide each year by traffic accidents and the costs of dealing with the consequences reach 518 million dollars. Brazil is in third place in number of deaths worldwide caused by traffic accidents [11].

3. INTELLIGENT TRANSPORTATION SYSTEMS - ITS

Intelligent Transportation System is a term assigned to the whole transportation infrastructure and procedures related to the transfer of information, communication, control, data processing and storage related to the transportation system [52]. It joins information technology system with automotive industry and this multidisciplinary nature increases the complexity of operations [7].
The term ITS is relatively new: Japan began developing ITS in the 70s. In United States the ITS can be seen in the 80s with studies related to the term Intelligent Vehicle Highway Systems - IVHS.

VANETS

It is possible to create a communication environment and data transfer between vehicles and infrastructure from ITS. VANETS - Vehicular Ad Hoc Networks, also known as Connected Vehicles, is a system that uses communication skills through wireless systems between vehicles and other infrastructure agents to make safer, smarter and more sustainable transportation system [12].

Ad Hoc networks are environments where devices are able to exchange information directly with each other. They emerged in the United States, around the 70s for military tactical purposes, where there was great need for mobility devices that could communicate over a network [13].

In Ad Hoc networks of its nodes can move arbitrarily and network topology adapts and reconfigures the best routes as needed. For this reason, ad hoc networks are mainly indicated in situations where it is not viable to install a fixed network.

VANETs enable communication:

- Between vehicles (V2V);
- Between vehicles and infrastructure (V2I);
- Among vehicles, infrastructure and other wireless systems (V2X).

4. ITS ARCHITECTURE

Base Technologies

The wireless communication protocol most widely used for V2V and V2I communications is the DRSC - Dedicated Short Range Communications. It is a short to medium range wireless communications (up to 1000 meters) that enables data transmission for public and private operations [14].

Here are listed how DSRC has been used in many parts of the world [15]:

• American DSRC: in November 2002 the FCC (Federal Communication Commission) requested the use of 75 MHz in the range of 5.9 GHz to DSRC;
• European DSRC: it is used the frequency range from 5725 MHz to 5875 MHz corresponding to ISM frequency band (Industrial, Scientific and Medical);
• DSRC in Japan: a standard not yet fully formalized, called ARIB T75 is being used for applications that use DSRC in the 5.8 GHz band;

In order to improve the dissemination of VANETS on the market, IEEE is developing a standard to operate in DSRC, entitled WAVE - Wireless Access in Vehicular the Environment.

This standard is built on the American DSRC [16] and will operate at the physical layer (PHY) of mobile devices in VANETs. The IEEE 802.11a standard along with the family of IEEE1609 protocols are used as a basis for WAVE (802.11p).

VITP - Vehicular Information Transfer Protocol, is another technology used in ITS, that belongs to the application layer, so it can operate independently of the DSRC. The basis of its structure is the GPS navigation system, wich provides any information based in geographical position, such as traffic conditions and routes [17].

LIDAR - Light Detection And Ranging is a remote sensing technology that uses light in the form of a pulsed laser to measure ranges (variable distances). The LiDAR instrument fires rapid pulses of laser light at a surface, some at up to 150,000 pulses per second. A sensor on the instrument measures the amount of time it takes for each pulse to bounce back [18].

LiDAR can be used in various applications. An Adaptive Cruise Control - ACC can automatically maintains a safe distance from the car in front. There are also vehicles with devices that find a parking spot and autonomously make a shot, without any human action [18].

Required Infrastructure

For the full operation of ITS, four areas are essential to its infrastructure: vehicular infrastructure, road infrastructure, operation center and mobile devices.

• Vehicular Infrastructure: It is a device for receiving and transmitting data that is installed in the vehicle, known as OBU - On Board Unit. It gathers all the information collected and enable communication V2V and V2I.
• Road infrastructure: It is a device located on roadsides, known as RSUs - Road Side Units. It enables V2I communications, and also sends data to the operation center [19]. Also, if required, RSU must be able to allocate channels to OBUs.

• Operation Center: Traffic information gathered is brought at the Operation Center, all operations and ITS command are developed, such as traffic control, detection of accidents/problems fleet management, allow of access to the network, and storage of data in the server [20].

• Mobile devices: Today the smartphone has a very important role in providing transit-related information, such as current location, alternative routes, traffic situation, public transport and even travel time forecasting, which ensures greater confidence about actions and better users decisions [20].

ITS Areas of activity and its impact on road infrastructure

Table 1 shows a summary table of all the recent research under the Intelligent Transportation System. We can classify the research regarding its main purpose: safety, mobility and sustainability.

Security

Nervousness, stress and depression, a sleepless night or even mixed feelings as excitement and euphoria greatly affect the handling of the driver. The same goes for alcohol. Many drivers consider themselves capable of driving even after consuming it in large quantities, reducing the rapid reaction capacity in several situations in traffic.

ITS brings more autonomy to the vehicle, as the system can calculate distances and speeds much more accurately, and thereby react more efficiently in risky situations [21].

Intersections are among the most complex elements and liable to traffic accidents of modern networks [22]. Studies indicate that most accidents at intersections are caused by errors of drivers [23], often as a result of misinterpretation of a situation, inattention or violation of traffic rules. In view of this, several recent papers have been developed facing these problems.

A study proposed method to avoid collisions at intersections without traffic light through V2V communication in order to improve safety at intersections [24]. An anti-collision algorithm was proposed based on Chinese traffic laws for the prediction of a possible accident and safe speed reduction before the accident occurs. Figure 1 illustrates this situation.

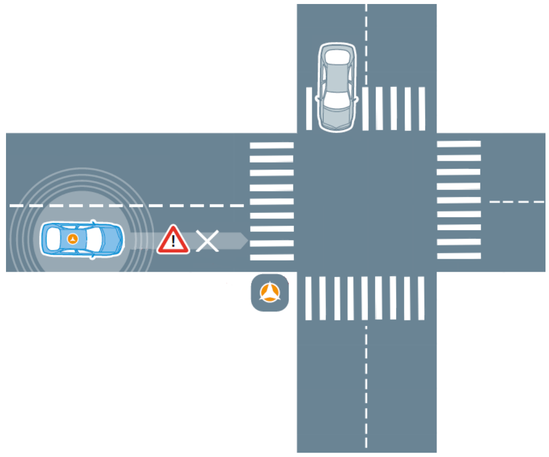

Fig. 1 – ITS Anti-colision system in intersections. Edited from [25].

Table 1 - Literature Review in ITS systems

YEAR	ARTICLE	AUTHORS	MAIN PURPOSE
2014	Vehicle Detection Based on LiDAR and Camera Fusion	(Bayless *et al.* , 2014)	Detection of obstacles
2014	Obstacle Recognition for ADAS Using Stereovision and Snake Models	(Liu, Huang e Zhang, 2014)	Detection of obstacles
2014	Traffic Signal Coordination for Emergency Vehicles	(Kang *et al.* , 2014)	Priority for special vehicles
2014	Real-Time Traffic Control for Sustainable Urban Living	(Xie *et al.* , 2014)	Traffic light time optimization
2014	Vehicle Speeds for Pedestrian Pre-Crash System Test Scenarios Based on US Data*	(Good e Abrahams, 2014)	Preventing accidents with pedestrians
2014	A Rear-end Collision Avoidance System of Connected Vehicles	(Li *et al.* , 2014)	Pileups prevention
2014	Precision Bounds of Pavement Deterioration Forecasts from Connected Vehicles	(Bridgelall, 2014)	Pavement Maintenance
2014	Traffic Signal Coordination for Emergency Vehicles	(Kang *et al.* , 2014)	Priority for special vehicles
2014	Collision avoidance at intersections: A probabilistic threat-assessment and decision-making system for safety interventions *	(R. De Campos *et al.* , 2014)	Preventing accidents at intersections
2014	Unsignalized Cooperative Optimization Control Method Based on Vehicle Speed Guidanceand Information Interaction	(Cai *et al.* , 2014)	Speed optimization at intersections

2013	Multi-stage Dynamic Programming Algorithm for Eco-Speed Control at Traffic Signalized Intersections	(Kamalanathsharma e Rakha, 2013)	Speed optimization at intersections
2013	Cooperative Collision Avoidance at Intersections: Algorithms and Experiments	(Hafner *et al.* , 2013)	Preventing accidents at intersections
2013	Mixed-integer NMPC for predictive cruise control of heavy-duty trucks	(Kirches *et al.* , 2013)	Automatic speed control for truck fleets
2013	Vehicular Trajectory Optimization for Cooperative Collision Avoidance at High Speeds	(Tomas-Gabarron, Egea-Lopez e Garcia-Haro, 2013)	Preventing accidents on highways
2012	Development and Evaluation of a Cooperative Vehicle Intersection Control Algorithm Under the Connected Vehicles Environment	(Lee e Park, 2012)	Speed optimization at intersections
2012	Dynamic Modeling of Driver Control Strategy of Lane-Change Behavior and Trajectory Planning for Collision Prediction	(Xu *et al.* , 2012)	Accident prevention for lane change
2011	Eco-driving at signalized intersections using V2I communication	(Rakha e Kamalanathsharma, 2011)	Speed optimization at intersections
2011	Intersection Collision Avoidance System Using Infrastructure Communication	(Basma, Tachwali e Refai, 2011)	Preventing accidents at intersections

Another model is proposed to avoid accidents between cars and pedestrians [5]. It is predicted when a pedestrian will cross a street, and the accident is avoided by sending an alert to the driver even before de pedestrian cross it. One of the major index of traffic accidents involve rear collisions. The use of V2V communication was studied to share information between vehicles and avoid a rear-end collision or a pileup [26]. The use system collects information such as position, speed and acceleration of the vehicle in front, as well as other data information such as the time of traffic light to predict the next vehicle action and determine a command to be taken by the driver. Figure 2 illustrates this situation.

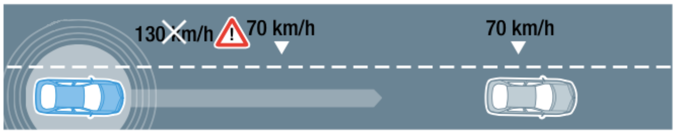

Fig. 2– ITS Anti- rear colision system. Edited from [25].

From a dynamic model of behavior of the driver control strategy in lane changes, applied to path planning in assisted steering systems it was created a system to help the driver identifying better lane change paths aimed at preventing collisions. Through emulation of different strategies, it is concluded that the maximum latitudinal position and the arrival time by the calculated trajectories can be good indicators of safe lane changes [27].

The Advanced Driver Assistance Systems - ADAS is in progress within the urban traffic area. Currently, ADAS are focused in detecting obstacles, particularly with regard to pedestrians and cars, but few studies have been conducted regarding the classification of multi-class objects. It was developed an approach to the simultaneous detection and multi-classes obstacles [28]. The stereovision is used to segment them using distance measurements and 3D coordinates, while the active control model (Snake Model) is adopted to extract a full curve control of detected obstacles. The characteristics of the object are then integrated for classification into types, such as vehicles, pedestrians and others. It was concluded that the combination of the two models results in a more reliable and accurate contour extraction.

Mobility and Sustainability

In the long-term, traditional solutions for traffic jam such as construction and remodeling of existing routes proved to be unsustainable measures [1]. It increases the length between origin and destination and does not solve the problem.

A solution that brings significant benefits without the need to build a new infrastructure is ideal for reducing costs and inconvenience in an urban environment. ITS came as a solution that brings significant benefits without the need to build new infrastructure. It gives more flow and organization to traffic, reducing the time and user travel expenses without causing interference in the city structure.

Mobility and sustainability are closely related. Greater congestion generate higher emissions of greenhouse gases and more fuel consumption. The impacts on the environment caused by the transport system are countless. Strategies such as navigation systems that tell drivers the shortest path, or even a more efficient control of the intersections generate savings in time spent on traffic, and thus, a reduction in fuel consumption.

A control of major intersections just with ITS and no traffic light is proposed [29]. It works through an algorithm that gather all the information collected by RSU's and calculate the optimal speed each vehicles so it can cross the intersection safely. This method can bring many improvements in mobility, reductions in greenhouse gas emissions and fuel consumption.

In a similar study, it was proposed an intersection with virtual traffic light were the RSU sends information to the OBU about the optimal speed and the safest time to cross the intersection. Experimental results indicated that there was a considerable reduction in the number of stops, the size of congestion and there was also an increase in the average speed of vehicles [30].

An algorithm was developed in order to optimize traffic light time through information collected from vehicles via V2I communication entitled ATSC - Adaptive Signal Control. The results showed a reduction in the number of stops, congestion and fuel consumption. Studies show travel time savings up to 61% and up to 32% savings in fuel consumption. Economies are more significant in moderate traffic [31].

Sustainability and mobility are also related to ensuring a better public transportation system, which reduces the number of vehicles on the streets. It is also related to give better conditions in emergency situations.

Busses can have priority in traffic with the use of ITS. The RSU locates the bus in the street and collect its schedule information. If the bus is late, the system gives priority to the it, changing the time of the traffic light and creating a "green wave" between two consecutive stops so the bus can get back to its regular schedule [32].

A study was made to propose ways of giving priority to emergency vehicles in order to control traffic lights [33]. The vehicle is captured through V2I communication and then a green light wave is created so the vehicle can pass. Even being an isolated action, it can bring impacts on traffic. Figure 3 illustrates this situation.

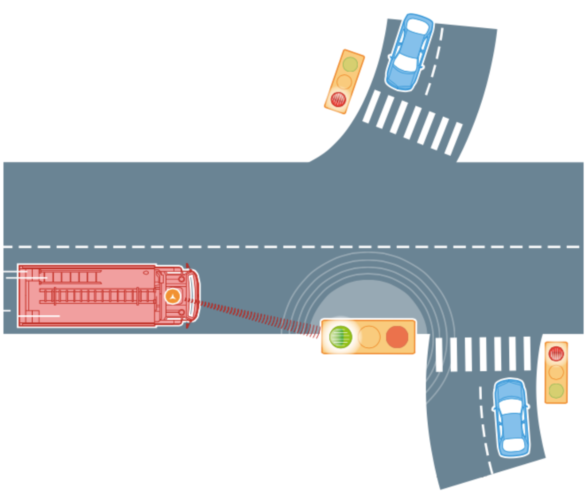

Fig. 3 - Priority system for emergency vehicles. Edited from [25].

A more effective maintenance of an infrastructure also generates a lower material and time consumption of the track operators, and also more safety for the track. Prevision models of regular pavement maintenance cycles require constant monitoring, but transportation agencies usually make an assessment of the pavement condition only once a year. [6] Proposes the use of Connected Vehicles to predict the correct time for maintenance of pavements. The author has developed a new approach called Road Impact Factor - RIF that is collected from a large number of inertial sensors on board of vehicles in a Connected Vehicles environment. Collected data through this system can predict with accuracy up to 95% when a floor may deteriorate.

5. CONCLUSIONS

In an ITS environment, all vehicles communicate with each other and with the infrastructure, and thus can provide a service and standard of personalized management for each vehicle passing through a road. This paper aimed to suggest the minimum required infrastructure and present the latest studies in the field from literature review.

There are still many challenges, but with this technology we intend to expand the exchange of information between user, vehicle and infrastructure to ensure a more efficient and safe transportation. New systems from the ITS have been developed around the world to solve the various problems in transportation. This is the first step in the development of future studies: the development of a speed control system at intersections through the ITS and the evaluatation of their impacts on a road infrastructure from mathematical formulation and simulation of the proposed method.

The simulation elements of an urban infrastructure as typical behaviors of drivers before certain situations, a vehicle flow interfering on the final speed of the vehicle and analyzing the influence of other intersections in the final result are essential to assess the real benefits of the proposed system.

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