

INFORMATION SYSTEMS APPLIED TO TRANSPORT IMPROVEMENT

SISTEMAS DE INFORMACIÓN APLICADOS AL MEJORAMIENTO DEL TRANSPORTE

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Received for review January 15 th, 2013, Accepted March 26 th, 2013, final version June, 15 th, 2013

ABSTRACT: Transport is one of the most relevant elements for the competitiveness of companies and cities. An inadequate transportation system generates high costs and low customer service levels, which ultimately produces a negative economic impact for both. This article presents an overview of the technology tools that are part of the Intelligent Transportation Systems (ITS) used to improve the performance and safety of transport, not only of cargo but also of passengers, in different modes such as air, maritime, rail and road. This article begins with a description of ITS, followed by the presentations of their benefits and, finally, it presents a review of the different tools for ITS.

KEY WORDS: Transport systems, ITS, ICT, City logistics, Communication systems.

RESUMEN: El transporte es uno de los elementos más relevantes para la competitividad de las empresas y las ciudades, pues un sistema de transporte inadecuado genera altos costos y bajos niveles de servicio al cliente, lo que finalmente produce un impacto económico para ambas partes. Este artículo presenta una revisión de herramientas tecnológicas que hacen parte de los sistemas de transporte inteligentes (ITS), sistemas utilizados para el mejoramiento del desempeño y seguridad del transporte, no solo de carga sino también de pasajeros y en diferentes modos. El artículo comienza con una descripción sobre los sistemas de transporte ITS, seguido por la presentación de los beneficios de estos sistemas y finalmente se realiza una revisión de las diferentes herramientas que enmarcan los ITS.

PALABRAS CLAVE: Sistemas de Transporte, ITS, TIC, Logística de ciudad, sistemas de comunicación.

1. INTRODUCTION

City growth generates an increase of traffic due to a higher movement of vehicles for the transport of people and the distribution of goods. This makes mobility problems more evident and more complex every day.

The problem of increased transport not only creates congestion problems, but also affects the economy, environment, health and competitiveness of cities and businesses. A collapsed transport system in a city means an economic problem since vehicles lose their ability to move easily; then their purpose, which is to move goods or people, is not developed properly, leading to higher transport costs, and affecting businesses and cities' economy. The environmental impact is

evident, since vehicles will have longer waiting times in heavy traffic locations or their trips will be made at a lower speed, creating higher fuel consumption, which produces more CO₂ and pollution. Besides, traffic jams make people impatient, and this is reflected in the use of horns, creating noise pollution. As for health, CO₂ emissions and pollution from fuel burning generate respiratory problems

In terms of competitiveness, companies and cities perform logistics operations less efficiently due to traffic, which involves higher costs and lower service levels, resulting in the mentioned competitiveness loss.

Internationally, there are strategies aimed at mitigating the negative impact of freight transport in cities [1,2], which are known as City Logistics Initiatives. City

logistics are based on reducing the number of trucks circulating within the cities, supported by a good integration strategy, allowing consolidation movements and thereby reducing the number of trips [2 - 5].

Taniguchi et al. [6] define city logistics as the process aimed to optimize the transport activities, with the support of advanced information technologies in urban areas, taking into account a set of initiatives that allow mitigating the negative effects produced by the vehicles used for goods transportation [6 - 8].

According to Crainic [4] and Arango et al. [2], city logistics strategies must be linked to an information system that allows an efficient administration process, aiming at the capture, processing, transmission, and management of that information. This has led to the development of specialized computer tools for transport management, such as the Intelligent Transportation Systems (ITS) and to the integration of administrative tools for operation management and decision making [2, 3].

However, the need to control transport operations outside cities is a key element to ensure quality and customer service. That is why ITS systems have also expanded to maritime, river and air transport, each with specific conditions, but with the aim of increasing productivity, customer service and therefore companies, cities and countries' competitiveness.

2. INTELLIGENT TRANSPORT SYSTEMS

According to Pillac et al. [3], during the last decade, a significant development of "smart" information technologies for vehicle routing management has emerged, based on technological advances in more accurate geographic information systems, new-generation of computers with increased processing capabilities, and developments of better planning systems and techniques.

The Ministerio de Fomento en España [9], defines intelligent transport systems as "... a set of advanced applications inside information technology, electronics and communications that, from a social economic and environmental standpoint, are designed to improve transport mobility, safety and productivity, by optimizing the use of existing infrastructure, increasing energy efficiency and improving the capacity of the transport system. Intelligent Transport Systems aim to respond, from a multimodal perspective, to the

transportation needs, applying ICT (Information and communication technologies)". Intelligent Transportation Systems are part of ICT, however Perego et al. [10] argue that some authors use the term ITS and ICT for transport without distinction [10, 11]. Therefore, the reader interested in exploring this subject should take note of this clarification and perform their analysis using the two possible names.

With the use of ITS, transport operations are performed optimally in terms of traffic flow (speed and time routes). Jarašūnienė [12] states that the integration of ITS allows the exchange and coordination of information, information acquisition and integration between vehicles and the road infrastructure, the exchange of information with private sectors (logistics service providers), and the exchange with non-transport-related organizations, such as electronic payment institutions.

Then, Intelligent Transportation Systems are the interconnection of different information systems aimed to capture, communicate, compute and assist decision-making, allowing to properly manage the flow of vehicles and transportation means [1]. For the proper management of a transport system, the integration of technologies such as the Internet, electronic data exchange, wireless communications, computer technology, programming, and technologies designed to capture and analyze the required information.[13].

2.1. Classification of ITS

When referring to ITS, it should be noted that they are grouped in two broad categories, ITS located in vehicles (such as communication systems and technologies inside them, and the so called "intelligent vehicles"); and the ITS located in the infrastructure or in the transportation mode, (such as dynamic signals, infraction control systems, etc.). In both categories great efforts and work to improve efficiency, based on the development of hardware, software and programming models to optimize routes and traffic flow, have been made [12].

Perego et al. [10] classify the main technologies for information and communication for logistics and freight transport, using four families, as follows:

- Applications for transportation management – TM
- Applications for supply chain execution - SCE

- Application for Field Force Automation - FFA
- Fleet and Freight Management Applications – FFM

TM applications are tools that allow the planning, optimization and execution of transport activities. They usually include cargo offer, routing, scheduling, tracking, freight payment and auditing systems. [14,15, cited by [10]]. SCE applications manage and automate the exchange of information, and manage the execution of the distribution schedule in real time [16 taken from [10]]. FFA applications are supported on mobile technologies and enable the integration between remote elements and business processes [17, taken from [10]]. FFM applications are used to report vehicles and freight information as well as to obtain real-time information to manage distribution operations in a more dynamic and efficient way [10].

Agre and Harbs [18] classify information systems applied to intelligent transportation on highways (IVHS - Intelligent Vehicle-Highways Systems) in six categories:

- Traffic and Travel Management Systems
- Public Transport Management Systems
- Electronic Payment Systems
- Commercial Vehicles Operation Systems
- Emergency Management Systems
- Advanced Systems for Vehicles

According to Jarašūnienė [12], these systems are integrated through an information chain that includes the capture, communication, processing, distribution and use of information by users (for management and decision-making). These users may be the regulators entities (as route managers) or may be drivers carrying passengers or goods. Figure 1 outlines the information chain described by Jarašūnienė [12].

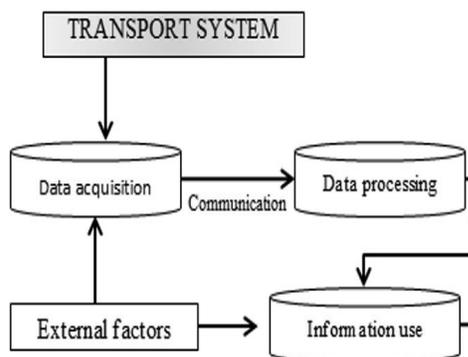


Figure 1. Information chain for ITS. Taken from [12]

3. BENEFITS OF ITS

According to Perego et al. [10] the impacts and benefits of ITS adoption have been studied by many authors [19- 23], from the point of view of increasing the efficiency and effectiveness of operations and including the improvement of corporate image. Table 1 summarizes the benefits found for each of the ITS categories presented by Perego et al. [10].

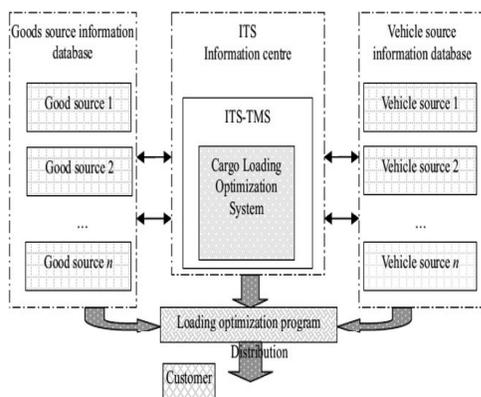
These systems, besides helping transport management to produce economically efficient and safe routes, also allow relevant information to users to be delivered, controlling congestion and traffic, managing cargo fleets and vehicles, optimizing infrastructure and managing communication between these elements.

ITS also allow to improve customer service as well as to obtain a cost reduction [32]. Zhibin et al. [32] state that through intelligent transport systems and their interaction with transportation management systems (TMS), it is possible to optimize freight processes inside cities, through the appropriate exchange of information between vehicle management systems and cargo management systems. This allows to merge these two information sources and then to develop distribution plans for optimizing the number of trips and the amount of cargo for each trip, producing a minimum total cost of the distribution system. Figure 2 shows the integration of these systems to produce the optimization of transport processes in city logistics approaches [32].

Based on the above, it can be argued that intelligent information systems are the set of multiple applications aimed to improve transport systems, for both passengers and cargo. These applications produce improvements and benefits reflected in more efficient traffic control systems, better identification of goods and people, improved multimodal management, increased security and comfort in transport, real-time information, reduced costs, among others.

Table 1. ITS benefits. Taken from [10]

Category	Benefits
Applications for transportation management	<ul style="list-style-type: none"> • Transportation management applications allow finding the most efficient way for goods movement in terms of time and cost [22]. • Transportation management systems allow programming shipping and optimizing routes, as well as supporting terminals operation management [26]. • It is possible to use the information generated by the system in order to make real-time analysis of transporters performance [22]. • These systems generate financial, environmental and fuel consumption benefits associated with cost reduction and routes optimization, which become evident in shorter total travel distances [25]
Applications for supply chain execution	<ul style="list-style-type: none"> • One of the most important benefits is the generation of greater information visibility and sharing across the supply chain [26]. • Applications for supply chain execution increase productivity, flexibility and the ability to exchange information throughout the organization [27]. • This kind of applications increases competitiveness of companies, improves resource coordination and carries out execution processes for order management, advanced planning, coordination, optimization and real-time adjustments in a more efficient way [28].
Applications for Field Force Automation	Their benefits are [24, 29, 10]: increased operation efficiency, reduced handling times, reduced delays, reduction in waiting times, reduction of manual efforts and stationery, resources optimization, better handling and transmission of information, increased connectivity, increased flexibility, and increased interaction among areas.
Fleet and Freight Management Applications	The benefits are [30, 31, 10]: improved internal operations, reduced use of paper, reduced waiting times, optimization in the use of available resources, minimization of costs and sources for materials input operations, faster response time to unexpected events, and better response to customer's requests.

**Figure 2.** Information systems integration to optimize city cargo transport [32]

4. TECHNOLOGY REVIEW

Table 2 summarizes the technologies available for ITS systems, which are divided into two main areas: In vehicles and In infrastructure technologies [10].

A key element for transport management with ITS is vehicle information acquisition, which, according to Jarašūnienė [12] can be obtained in three ways:

- **Inductive Detectors.** These detectors are devices installed in the pavement, which allow taking a census of vehicles. These sensors can determine the number of vehicles, their speed and the traffic on a road.
- **Ultrasonic, infrared and radar sensors:** These sensors are placed on towers. They can detect vehicles using waves and determine the number of vehicles and their speed. The advantage of this system over the inductive sensors is the easy installation and maintenance, but in adverse weather conditions, their performance is less efficient than the others.
- **Video imaging detectors:** These detectors can recognize the presence of a vehicle and its speed, track occupancy, traffic flow, detect license plate,

etc., through image processing, based on optical character recognition (OCR) [33].

In addition to these elements, it is essential to establish a control center in order to monitor and make decisions to improve traffic conditions in the city. It is thus necessary to have a Close-circuit Television (CCTV) system as a

complement to the vehicle detection devices. Another important element when getting the traffic information is to keep suitable communication with the institutions related with the transportation system, such as traffic agents, helicopters, road maintenance system, taxi companies, weather system and even navigation applications used in mobile phones [12].

Table 2. Technologies available for ITS [10].

Technology	In infrastructure	In vehicle
Location	Digital Maps, Geographic Information Systems, Transport Network Databases	Cell Phone Location, Global Navigation Satellite Systems, Automatic Vehicle Location
Information Acquisition	Traffic Detectors, Time Monitors, Automatic Incident Detection	Automatic Vehicle Identification, Vehicle Checking and Exploration
Information Processing	Data Dictionaries, Data Fusion, Data Exchange	On-board computers, Digital maps matching
Communication	Fixed Microwave Links, Optical Fiber Networks, Beacons (DSRC), Mobile Network	Digital Radio Tuners Receivers, Mobile Receivers, Highway Radio Ads, Signal Converters
Information Distribution	Signals for Dynamic Messages, Internet, Telephony Points	Hands-free, Personal digital assistants
Information Usage	Incident Detectors, Demand Management, Traffic and Congestion Monitoring	Routing Guides, Driver's Advanced Support Systems

To understand traffic system behavior, it is important to determine how it works. For doing so, there are simulation tools, which have become very practical and easy to use. They can emulate the behavior of the traffic system characteristics and make decisions based on it [34].

Also, there are several applications that process the information which are aimed at generating traffic system reports for managers and users. According to Jarašūnienė [12], in order to obtain this information, it is necessary to “merge” the information from both public and private sources. This information can be delivered to both actors through dynamic signals (Dynamic Message Signs - DMS), to broadcasters and television, in-vehicle devices (In-Vehicle Units - IVU) or handheld devices.

Others systems available for ITS are:

- Automatic Incident Detection - AID: These systems reduce incident detection time and response time to them. They also allow determining the possibility that an accident may have occurred or may occur, by tracking traffic patterns. These systems are not designed to replace the monitoring centers, but to help their management [12].

- Weigh in Motion - WIM: These systems are designed to determine the weight of vehicles in motion. They can help control the care of roads, since an overweight vehicle is a factor for their premature deterioration. These systems work thanks to the location of load cells, piezoelectric systems or flexible bands. Figure 3 shows a photograph of a flexible band WIM system [35].



Figure 3. WIM system of flexible bands [35]

- Advanced Traffic Management Systems - ATMS: These systems are in charge of acquiring real-time information about traffic conditions, data analysis, travel time predictions, emergency response management and providing this information to users through information systems of the city traffic

control or other means such as Advanced Traveller information Systems – ATIS. Those are responsible for providing traffic information, which can be used by users to improve their transportation mode selection, routes and decision-making in general. These systems allow the reduction of distances, fuel consumption and pollution.

- Electronic payment and Automated Vehicle Identification – AVI: These systems allow the real demand and the current amount of trucks circulating in real time to be known, making it possible to control the flow of transport within the city.
- Advanced Fleet Management Systems -AFMS: These systems allow the positioning and use of freight to be planned, resulting in the system’s optimization and its control in real-time. According to Benjelloun et al. [1] “Advanced Fleet Management Systems can contribute significantly to the efficiency and ultimate success of cities’ logistics systems”.

4.1. ITS in different transport modes.

ITS have been developed more in some transport modes than others, according to the needs and development of the modes. Thus, information systems for airplanes have been far more advanced than for any other mode, due to the need for security and monitoring of aircraft.

The most important element in the advance of communications for transport lies in the ability to communicate vehicles with a control center that allows its management. For example, vehicles can inform their position to their fleet manager through a mobile communication link. Long-range radio communications allow ships to communicate over long distances with other vessels; Global System for Mobile Communications - Railway (GSM-R) enables efficient wireless connectivity for trains; and transponders (devices used to identify aircraft automatically) [9].

Table 3 presents a review of the most relevant technological elements used in different modes for their intelligent management processes.

Table 3. Technologies available for ITS [12].

Mode	Description
Air	The most important technological elements in the air transport mode are the maneuvers support systems for aircraft landings and takeoffs (ILS - International Landing System and MLS - Microwave Landing System), navigation aid systems (VOR - VHF Omnidirectional Range, GNSS) and radars.
Maritime	In maritime transport, the most representative elements are the Automatic Identification System –AIS-, and the positioning and communication systems GNSS (Global Navigation Satellite Systems). In this mode of transport, the radio-electric systems to aid navigation are widely used. Terrestrial or satellite radio-navigation systems such as LORAN-C type (Long Range Aid for Navigation), GPS - Global Positioning System and radar, (Radio Detection And Ranging) have been key technological elements to avoid collisions and to allow the development of this mode of transport.
Rail	In rail transport, the highest technological development is clearly seen in the railway traffic management systems, such as the European Rail Traffic Management System - ERTMS, which is composed by: ETCS (European Train Control System) and GSM-R (Global System for Mobile communication - Railways). For railway traffic management in cities, systems such as the Automatic Train Protection - ATP, or the Automatic Train Operation – ATO are used, which enable an integral management of the rail network, producing a safe and high quality service, and reducing the system’s energy consumption.
Road	In road transport, the most important technological elements are related with positioning systems like GPS and traffic monitoring through cameras. These systems can be used for automatic incident detection (AID), toll management, urban transportation control, congestion detection, in-tunnel control, speed control and calculation, dangerous goods transport control, infractions detection, among others. Other relevant technological elements for road transport are the Advanced Driver Assistance Systems –ADAS- and the In-Vehicle Information Systems IVIS -, which provide users with information about secondary tasks related to transport, such as navigation.

4.2. Communication between vehicles and infrastructure

Vehicle and infrastructure communications are a key element in intelligent transportation systems, since they allow two-way communication, which is used by city managers to obtain information for transport management and transmit it to users. The Vehicle-to-vehicle communication - V2V-and the Infrastructure-to-vehicle-communication - I2V [33] are included in those communication systems.

According to Borrero et al. [33], there are a large number of devices that allow communication via internet at any place and at any time. So that a vehicle equipped with its own IP and an Internet connection can be connected to a control center (I2V) and/or to other vehicles (V2V). Other ways of connections are via Bluetooth [33] and through telephone lines located among vehicles. Communication among vehicles, as well as in aviation and maritime transport, can reduce collision probability and improve traffic through the exchange of information about traffic jams and accidents.

This communication has generated the development of cooperative systems between vehicles and infrastructure CVIS (Cooperative Vehicle-Infrastructure Systems), which allow interaction among nearby vehicles and infrastructure located on the roads, offering better traffic and transport management. CVIS systems are based on a multichannel terminal capable of connecting a wide range of devices through WLAN / Wi-Fi, cellular networks (GPRS / UMTS) short frequency microwave and infrared and satellite communications [36].

This communications leads to a new concept called Connected Transportation System, which is an attempt to connect vehicles through some communication technology, what allows improve safety and emergency management, as well as the transport management and environmental impacts. According to Dimitrakopoulos [37] the most feasible communication technology is the IP based infrastructure.

The development of these systems allows transmission of relevant information for travelers such as:

- Routing
- Traffic management and congestion avoidance

- Traffic signal coordination
- Truck monitoring
- Parking space management
- Safety information and warning announcements
- Weather information

4.3. Traffic Management Technologies

The technologies for traffic management are a set of tools that aim to reduce congestion in cities, while improving traffic security. These technologies distribute traffic and alert drivers about the various problems they may encounter on the roads [38]. According to WSDOT [38] the main element of these technologies is the ability to constantly adapt to traffic conditions, and respond to these changes efficiently.

Government Procurement Service [39] mentions that the traffic management technologies are part of a framework that enables access to a wide range of technologies such as: solutions for traffic management, traffic signs and parking systems, electronic and interactive message systems, traffic monitoring services, vehicle access and parking services, among others.

4.4. Weather Responsive Traffic Management

Weather Responsive Traffic Management - WRTM are a set of technologies that predict, determine and anticipate weather conditions, so it is possible to execute care and control actions before weather conditions affect the roads [40]. These systems allow suggestions to be made and strategies to be developed to mitigate climate impacts, and the information is transmitted to the managers and users through communication systems with vehicles and control facilities. Thus, Traffic Management Technologies are a combination of techniques, tools, and systems that authorities use to mitigate weather impacts on transport processes [40, 41].

According to the USDOT [40] actions to be undertaken to develop traffic management systems in response to climate are:

- Motorist Advisory, Alert and Warning Systems
- Speed Management Strategies

- Vehicle Restrictions Strategies
- Route restrictions Strategies
- Traffic Signal Control Strategies
- Traffic Incident Management
- Personnel/Asset Management
- Agency Coordination

WRTM are based on several technologies such as:

- Passive warning systems
- Active warning systems
- Pre-Trip Road condition information and forecast systems
- En-Route weather alerts and pavement condition information

The joint use of these technologies seeks to improve transport systems, specifically the safety and mobility of passengers and cargo. This has led to the development of more complex strategies, such as the Smart Roadside Initiative, which seeks to improve safety, reduce the number of accidents and increase efficiency in the movement of goods through the collection and sharing of information between commercial vehicles, carriers, highway facilities, intermodal platforms, tolls and other elements of the transport system [42, 43].

This integration is achieved through the joint operation of technologies and information exchange between three elements: vehicle communication systems, technologies in roads and the systems used in the cargo transportation processes [42].

5. CONCLUSIONS

Transportation determines companies' competitiveness and has several negative effects on cities, creating a necessity to make great efforts in management processes. The later explains the need for advanced information systems that lead to transport optimization at all levels, both for commercial and passenger transport.

Intelligent transport systems are tools to allow transport mobility, safety and productivity to be improved, and involve many aspects for this purpose. That is the case

of the information coming from vehicles, public and private entities, and the information obtained from systems and information technologies such as cameras, radars and speed detectors. All this allows intelligent transportation management to be achieved, which is the primary objective of ITS.

This paper has presented a review of technologies for ITS. However, it did not address the computational tools that would optimize these systems. This is why, as a conclusion, the importance of developing programming tools and models that will help to improve transport operation and management through ITS is outlined. It is also recommended to carry out studies that allow the most successful experiences worldwide to be analyzed and try to apply these tools in the Colombian environment.

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