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Analysis of the implementation of telematic tools for data management of passenger traffic dynamics in the Bus Rapid Transit system

Análisis de la implementación de herramientas telemáticas para la gestión de datos de la dinámica del tráfico de pasajeros en el sistema Bus Rapid Transit

Análise da implementação de ferramentas telemáticas para a gestão de dados da dinâmica do tráfego de passageiros no sistema Bus Rapid Transit

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Abstract

This article briefly describes the transport system of the Republic of Ecuador and, in particular, the organization of the route network of urban passenger transport in Quito, the capital city of Ecuador. The features of the organization and management of transportation of passengers on the main routes of urban passenger transport of Quito are determined by the Bus Rapid Transit (BRT) system. We revise possible ways of improving the management and control of urban passenger transport in Quito by using telematics tools and systems. We propose that the main direction of improvement is to introduce tools for assessing the dynamics of passenger traffic in real time through the use of telematics. In comparison with traditional systems, the peculiarity of the approach proposed is the use of telematics equipment and special sensors for calculating the number of incoming/outgoing passengers from the vehicle, which are installed directly in the doors of the pavilions of the bus stops of the BRT system routes. The goal of this approach is to reduce the cost of telematics equipment and normalize the occupancy inside transport vehicles, which is one of the service level indicators.

Keywords: public transport; road transport; telematics; teleinformatics.

Resumen

El artículo brinda una breve descripción del sistema de transporte de la República del Ecuador y, en particular, de la organización de la red de rutas del transporte urbano de pasajeros en Quito, su capital. Las características de la organización y gestión del transporte de pasajeros en las principales rutas de transporte urbano de pasajeros

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de Quito están determinadas por el sistema Bus Rapid Transit (BRT). Se revisan las posibles formas de mejorar la gestión y el control del transporte urbano de pasajeros en la ciudad mediante el uso de herramientas y sistemas telemáticos. La dirección principal de mejora, según los autores, es la introducción de herramientas para evaluar la dinámica del flujo de pasajeros en tiempo real a través del uso de la telemática. En comparación con los sistemas tradicionales, la peculiaridad del enfoque propuesto es el uso de equipos telemáticos y sensores especiales para calcular el número de pasajeros entrantes/salientes del vehículo, los cuales se instalan directamente en las puertas de los pabellones de las paradas de autobús de las rutas del sistema BRT. El objetivo de este enfoque es reducir el costo de los equipos telemáticos y normalizar la ocupación en el interior de los vehículos de transporte, que es uno de los indicadores de nivel de servicio.

Palabras clave: transporte por carretera; transporte público; telemática; teleinformática.

Resumo

O artigo apresenta uma breve descrição do sistema de transporte da República do Equador e, em particular, da organização da rede de rotas do transporte urbano de passageiros em Quito, sua capital. As características da organização e gestão do transporte de passageiros nas principais rotas de transporte urbano de passageiros de Quito estão determinadas pelo sistema Bus Rapid Transit (BRT). Revisam-se as possíveis formas de melhorar a gestão e o controle do transporte urbano de passageiros na cidade mediante o uso de ferramentas e sistemas telemáticos. A direção principal de melhora, segundo os autores, é a introdução de ferramentas para avaliar a dinâmica do fluxo de passageiros em tempo real através do uso da telemática. Em comparação com os sistemas tradicionais, a peculiaridade do enfoque proposto é o uso de equipamentos telemáticos e sensores especiais para calcular o número de passageiros que estão entrando e saindo do veículo, os quais se instalam diretamente nas portas dos pavilhões das paradas de ônibus das rotas do sistema BRT. O objetivo deste enfoque é reduzir o custo dos equipamentos telemáticos e normalizar a ocupação no interior dos veículos de transporte, que é um dos indicadores de nível de serviço.

Palavras chave: transporte por estrada; transporte público; telemática; teleinformática.

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I. Introduction

Currently, according to statistics, Quito, capital of Ecuador, has around 3.5 million inhabitant. Urban passenger transport management is organized within the framework of the "Integrated Land Transport System of Quito". In this system, most of the passenger transport is carried out in the trunk corridors that work under the Bus Rapid Transit (BRT) system. Similarly, to increase the capacity of the road, only trolleybuses and articulated buses with high passenger capacity are used. The "Trole" line in Quito provides an early example of BRT in Latin America. The BRT system in Quito covers up to 95% of the urban area [1-3]. The capacity of an articulated trolleybus is 150 passengers, while that of buses can reach up to 160 passengers. In addition, Quito has new biarticulated bus units with a capacity of up to 270 passengers.

The BRT system was created to guarantee a bandwidth of passengers flow in the most congested sections of the city by increasing the travel average speed. This was achieved by organizing differentiated lines in the main corridors of public transport, thus separating the bus and trolleybus traffic line from the private vehicles line.

The characteristics of the urban transport organization with the BRT system are:

- Buses and articulated buses with high passenger capacity
- Boarding and disembarking of passengers take place in special closed stations (pavilions)
- Ticket is paid at the entrance of the pavilions, and passengers pass through a tourniquet
- Transportation is carried out on differentiated lines that separate the BTR from the rest of the private transport, either by physical (border) or descriptive separations (paint strokes)
- Informative panels are used to inform passengers about the arrival time of the vehicles
- A dispatch system controls transportation [1, 4]

The construction of the infrastructure for the BRT system in Quito began in 1994. The system is organized under the example of the Brazilian city of Curitiba, pioneer in the implementation of this type of transport systems [1]. The BRT system provides a high quality transport service, like the metro service, but at a lower price. In this sense, the BRT system is known as the "subway on the ground" system.

II. Methods

A. Analysis of the existing system for passenger transport planning and control of trunk routes

Operator Unit of the Trolebus System (UOST), a specialized company of the Transport Services Organizing Unit of the municipality of the metropolitan area of Quito, is in charge of planning the work of transporters in the public transport system. The company is responsible for planning and controlling the work of the integrated passenger transport system on trunks and feeder routes [5]. A software developed and launched in April 2003 plans the transport by applying mathematical models that determine the intervals of bus traffic and their distribution on the routes. The software uses a statistical database that determines the transport demand by citizens.

To control the operation time and execution of the vehicles on each route, they are equipped with communication and satellite navigation terminals that use GPS receivers. Transport control technology based on the analysis of navigation data replaced the traditional control system based on control points for each route, which used clocks with time markers of operation. However, data on passenger flow is currently recorded manually, with a part being entered manually into an Excel database at the control center. The lack of adequate information on the flow of passengers results in the following drawbacks:

1. It is not optimal, and, therefore, the movement organization in the urban transport trunk corridors is less effective
2. The distribution of the bus and trolleybus fleet on the routes is not optimal according to the hours of the day and days of the week.
3. The control system lacks operational reaction to the acute fluctuations of passenger traffic.

B. Proposals to improve the efficiency of the transport management system on the trunk routes

Solving the deficiencies mentioned above is possible through the introduction of instruments and automated systems that collect and process passenger flow data.

The availability of a modern information system for collecting and processing data on the parameters of passenger flows, even in real time, makes it possible to manage the transport resources at hand more efficiently. Operational and statistical information on passenger flows allows to a) control and regulate the dispatch process, according to a scheduled transportation service, b) estimate the average bus waiting time at the stations, and, c) analyze the dynamics of passenger traffic during rush hours and count the number of passengers transported.

The data received on passenger traffic during the trips facilitate creating a passenger demand model that can be used for transportation planning (schedules organization). In addition to this model, the initial data allow to build a predictive model of passengers flow along a route and occupation of the vehicle; this model allows maintaining the transport quality within a determined range.

Currently, the main instrument to eliminate the deficiencies of the system is an automated system to monitor passenger flows. In the United States and Europe, these systems are called Automated Passenger Counting (APC) System. In Russia, this system have been successfully used for 15 years in urban passenger transport [5]. This system uses an on-board telematics equipment with two main components: an on-board navigation and communication equipment and an equipment for automatic counting of passengers entering and exiting the vehicle (Fig. 1).

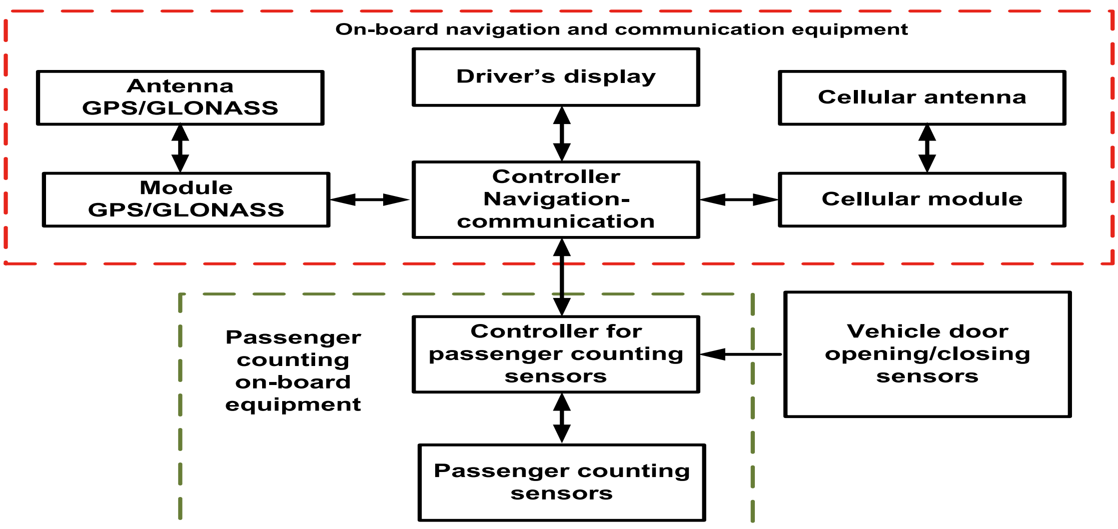

Fig. 1. Interaction scheme of the components of the on-board equipment of the APC System.

The passenger counting controller represents an active link, to which the opening sensors of the vehicle doors are connected. Therefore, if the vehicle has three doors, the controller interrogates the three sensors of each open door [6].

In Russia, the most popular equipment is manufactured by the German firm IRIS Gmbh [7]. To calculate the number of passengers entering or leaving the vehicle, a sensor is installed above each door. The sensor contains a transmitter of infrared signals and a receiver of reflected signals. While the doors are closed, the sensors are inactive. When the door-opening signal is received, the sensors turn on the active and passive components that operate in the infrared spectrum. The disturbances created by the passing passengers are detected by the sensor, at that moment, the infrared signal is reflected from the passenger head and shoulders. The receiving set of sensors for automatic counting passengers is able to form a discrete 3-D model of objects located at the entrance, which consists of 500 independent measurements of the distance from the sensor to the objects. When all doors are closed, the sensor data is specified in the format [door number] [entry number] [exit number] and is transmitted to the on-board telematics unit (device), which adds location data (latitude, longitude, date/time). The received data is transmitted through wireless communication channels for further processing, in order to obtain real data on passenger traffic [8-9].

The main disadvantages of this technology are the high cost of the on-board equipment for passenger counting and the interference with the construction of the vehicle when the equipment is installed. Furthermore, the equipment itself consumes additional energy, and in case of replacing the vehicle, it is necessary to dismantle and re-install the on-board equipment. Finally, at some point, only a part of the total set of the on-board equipment is used, because not all vehicles in the fleet are serving for technical or organizational reasons.

C. Proposal for using telematics equipment for passenger counting in the BRT systems on mass transport trunk routes

Given the characteristics of the organization of passenger transport in the main routes of the Quito BRT system, the disadvantages mentioned above can be avoided by installing the equipment directly in the pavilions and not in the vehicles (Fig. 2). In this case, the sensors should be placed directly above the passenger entry and exit doors inside the pavilions, and should activate automatically when opening and closing the doors.

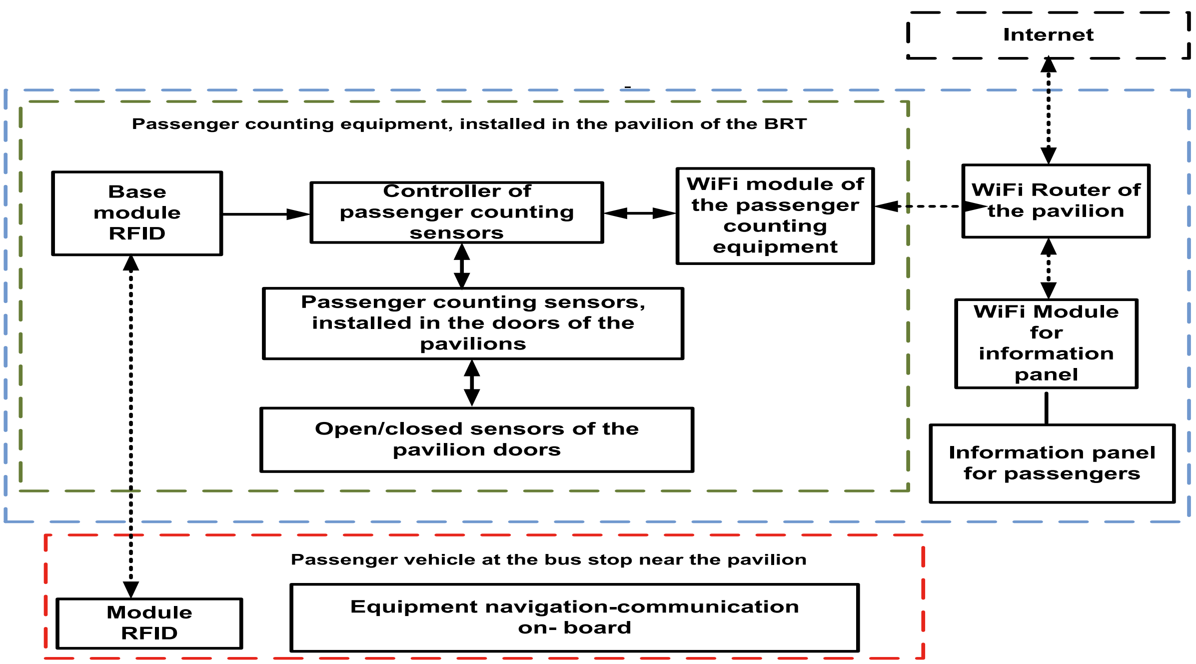

Fig. 2. Proposed scheme for placing passenger-counting equipment in the pavilions of the BRT system.

This scheme will be economically viable if the number of vehicles operating on the trunk routes is significantly bigger than the pavilions that must be equipped. Currently, in the three main corridors of Quito, in general, 113 trolley buses, 160 articulated buses and 80 biarticulated buses are moving along 22 routes; a total of 353 vehicles and 1219 doors for entry and exit of passengers. The number of pavilions in the three main corridors is 111 with a total of 674 doors. Therefore, the cost of the passenger counting equipment is two times more profitable if it is installed in the pavilions.

The equipment in the pavilion should include the following elements: a) a passenger counting controller, and b) passenger counters that should be installed above the doors and connected to the controller; the sensors that open the pavilion doors should also be connected to the controller. Pavilions should have an internet connection that allows using the WiFi router to transmit information on incoming/outgoing passengers, as well as installing and connecting a passenger information panel, and providing "free of charge" internet service. Additionally, we propose to connect a Radio Frequency Identifier (RFID) module to the controller for the automatic identification of vehicles approaching the pavilion; for this, the vehicles will be equipped with a passive RFID module.

According to this proposed scheme, the control team will operate in the following manner:

1) When arriving to the pavilion, the driver will control the opening and closing of the pavilion door according to the existing technology
2) The on-board RFID module will identify the vehicle automatically
3) The RFID will transmit the identification information to the passenger counting sensor controller.
4) When the pavilion door is opened, the door sensors will activate.
5) After receiving the signals from the door sensors, the controller will activate the passenger counting sensors located above the respective pavilion doors.
6) Once the door closing signal is received, the controller will deactivate the passenger counting sensors, update the information on the number of incoming and outgoing passengers, along with the vehicle and pavilion identifiers and the arrival and exiting time of the vehicle, and send this information to the control center for further processing.

Table 1 provides a description of the main information processes of the proposed passenger counting system for the main routes of Quito.

Table 1

Description of the information processes of the proposed passenger counting system for the trunk corridors of Quito

№	Description of the work stage	Input parameters	Results formulated
1	Waiting for the pavilion door state to change from “closed” to “open”	Information package with change of door status	State of the door: “open”
2	Start counting the number of incoming / outgoing passengers	Signals from the infrared sensors are interpreted as the number of incoming / outgoing passengers	Number of incoming / outgoing passengers through each vehicle’s door
3	Waiting for the pavilion door state to change from “open” to “closed”	Information package with change of door status.	State of the door: “closed”
4	Automatic counting system working. Transfer of data to the proposed system server, according to the format of the data exchange protocol	Instruction to formulate the information package	1) Unique number of the RFID sensor 2) Number incoming / outgoing passengers 3) Additional information
5	Identification of the vehicle to which the results of the automatic passenger count are assigned	1) Unique number of the RFID sensor 2) Number incoming / outgoing passengers 3) Additional information	1) Vehicle 2) Pavilion 3) Entry 4) Exit 5) Door number

№	Description of the work stage	Input parameters	Results formulated
6	Travel assignment, definition of pavilion, calculation of the passenger's in cabin	1) Vehicle 2) Pavilion 3) Entry 4) Exit 5) Door number	1) Itinerary 2) Route 3) Pavilion 4) Entry 5) Exit 6) Cabin occupancy 7) Identification of the vehicle
7	Data transfer to the dispatch system. Accumulation of data to calculate the statistical parameters of the passengers flow on the route for the different periods of the day	1) Itinerary 2) Route 3) Pavilion 4) Entry 5) Exit 6) Cabin occupancy 7) Identification of the vehicle.	Management of the dispatch schedule execution

III. Results

One of the advantages of having pavilions at each stop is the ability to determine the occupancy of people in the pavilion in real time. With this objective, we propose to equip doors of each pavilion with sensors. This allows to determine the occupancy of each pavilion in real time and transfer this data to the dispatch center for the analysis of the situation. If the limit of occupancy for each pavilion is established in real time, then, the pavilion load level can be calculated as the relation between the current number of passengers in the pavilion and the maximum number allowed. To control this new parameter, the data structure, formatted by telematic equipment for the pavilion, can be as follows: [date /current time, ratio of current number of passengers inside the pavilion/limit of passengers allowed inside the pavilion, pavilion number].

The information on the actual saturation of the pavilion will allow to estimate the capacity of this element of the network infrastructure in the main routes of Quito.

IV. Conclusions

1) The additional information on the flow of passengers, obtained thanks to the online input measurements, provides the dispatch system with new possibilities on trunk routes.

2) The proposed solution does not change the door management system of the existing pavilion, neither the existing system of planning and control of the movement of passenger vehicles, it only complements it.

3) The successful practical implementation of the proposal described in this article can reduce the cost of telematic equipment of passengers counting in relation to traditional systems that use such equipment.

Authors' contributions

María José Duque provided the introduction and analysis of the current situation of transport in

Ecuador; Veniamin N. Bogumil, the elaboration of Work Plans of the On-board Equipment; Aleksandr A. Kudryavcev, the development and elaboration of the functioning table of the telematic equipment; and Veniamin N. Bogumil and María José Duque, the analysis and proposal of use of telematics equipment for the transport system of Quito.

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