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# Advanced fleet management systems for public transport

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**ABSTRACT**
The objective of this paper is to present the latest findings and trends in the evolutions of fleet management systems for public transport. The architecture of the current systems will be analysed together with the expected evolutions.

**KEYWORDS: fleet, management, control, security, transport, telematics**

## 1. Introduction

Fleet management systems within public transport were introduced more than 20 years ago, aimed at supporting the operations and improving the productivity of the transport operator. From this point in time, the evolution has been continuous, based on the availability of new technologies such as GPS, mobile communications, etc. that has enabled the provision of new advanced services. The GMV develops and provides state-of-the-art fleet management systems, being one of the European leaders in this area.

The objective of this paper is then to present the latest findings and trends in the evolutions of fleet management systems for public transport. The architecture of the current systems will be analysed together with the expected evolutions, putting special emphasis on the communications between the vehicles and the control centres, together with the incorporation of passenger multimedia systems and the latest security measures, such as video surveillance systems that can be remotely managed from the control centre. Finally, this paper will also review the operational benefits that can be derived from these kinds of systems together with the areas in which improvements can be still achieved, from different points of views: public transport authority, service provider or concessionaire and the passengers.

## 2. Architecture of fleet management systems

### 2.1. High-level architecture

Fleet management systems for public transport have experienced a significant evolution in the last years, as long as new technologies and applications have been made available, basically related with the Information and Communication Technologies (ICT). The functionalities that can be performed by these systems have been then expanded, so they are progressively becoming more and more sophisticated. From the architectural point of view, one of the latest findings has been the development of intermodal and multi-operator fleet management systems, so this article will take this as the basis. Simpler systems can be easily explained by the removal of functionalities.


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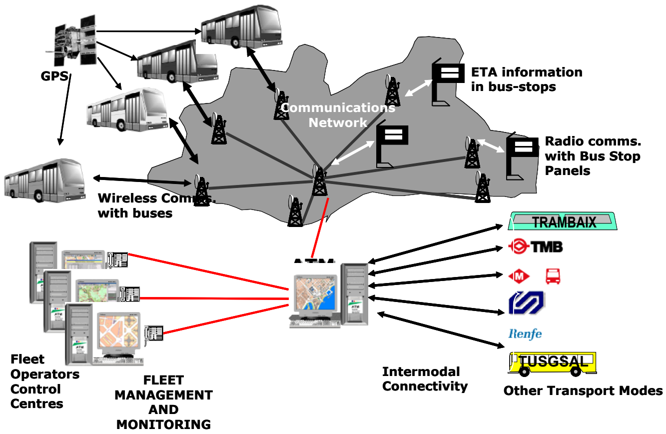


Fig. 1. High-level architecture of advanced fleet management system for public transport

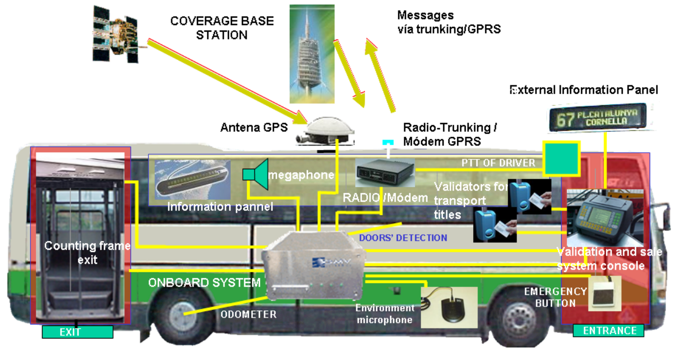


Fig. 2. Vehicle On-Board Unit and other equipment

A fleet management system is named as intermodal when it is interconnected with other means of transport (air, rail, ...), not only in terms of the exchanging of information useful for the company but also offering users overall information on the status of the transport in their area. This means, for example, to show any relevant information concerning other transport systems (for example, interrupted service in the rail system between two cities) on information boards at bus or tramway stops, in real-time and in an automatic way. See additional information in reference [4].

On the other hand, a fleet management system is named as multi-operator when it is capable of managing simultaneously at the same time several fleets from different operators. The sharing of resources (communications system, control centre, human management resources, etc.) creates beneficial economies of scale, as well as a great level of coordination between the different operators and the transport authority.

The high-level architecture of the system is depicted hereafter in Fig.1. The core of the system is the master control centre, connected with the corresponding ones of each individual operator. The vehicles are equipped with an On-Board Unit (OBU), which controls all the telematic equipment of the vehicle and communicates in a bidirectional way with the control centre. Information boards can be deployed in stations and stops with the main purpose of providing information to the users. Connections with other means of transport and with the Traffic Management System (TMS) are done through the master control centre, while connection with the ticketing system is done bus by bus between the OBU and the ticketing machines.

The communications network can be based on different technologies: radio, mobile telephony (GSM/GPRS/UMTS), Trunking / TETRA, etc. The trend is to use the mobile telephony taking advantage that with GPRS at least the bandwidth for data transmission in normal operations is sufficiently high and there is no cost for the system set-up and deployment. Wi-Fi, Bluetooth, Ethernet or fibre optics connections can be used depending on the availability. For example, a Wi-Fi or Bluetooth connection point can be established at the extremes of the line to allow non real-time data discharging without using mobile communications.

The master control centre, allocated to the transport authority, will host the central database of the system with the capability to monitor all the elements of the systems (panels, vehicles, etc.), but it will only control those elements that are under its direct responsibility, as for example information boards at stops, information through internet or SMS, and the intermodal connectivity with other means of transport and the Traffic Management System (TMS). Every fleet operator will host a control centre, which will be connected in real-time to the master one in order to synchronise the information of their local database and the central one concerning their vehicles and their information boards. Each operator will only have access to that part of the central database directly related to the service, precluding therefore the access to any information from the other operators and thus maintaining the confidentiality.

## 2.2. Vehicle on-board units

The core of the vehicle telematic infrastructure is the so-called vehicle On-Board Unit (OBU). Its main functionality is to provide localisation and communication with the control centre, besides controlling and monitoring all the subsystems of the vehicle to a maximum extent. It is important to say that this is not a safety-critical system, so control of vehicle engine is totally excluded. The OBU is basically composed of one or more industrial PCs, depending on the level of complexity, that share the different tasks and works interconnected between them by means of a vehicle internal LAN. This OBU normally incorporates the GPS receiver and the GSM/GPRS/UTMS modem too, while the antennas are located externally on the vehicle. A schematic view is shown in Fig.2.

Localisation is basically achieved by means of the GPS signals, although the OBU is normally connected to the odometer of the vehicle to help solving its position whenever the GPS signals are lost because of high buildings or because the vehicle is inside a tunnel. In certain cases, an inertial system could be also added in order to have a fully redundant and independent system, but they are seldom used.

The OBU can be connected to the ticketing device, validators for transport tickets (contact or contactless cards) and the passenger counting devices installed at the doors to measure the number of passengers that get down. Thanks to this it is possible to establish at any moment the number of passengers that are inside the vehicle. Depending on the purpose (either to pursue the fraud or to have data for operational analysis) the passenger counting system will be required to provide a certain level of accuracy, typically below 1% and 10% respectively, and thus it will rely on different technologies.

Another important functionality of the OBU is to manage the message and voice communication between the vehicle driver and the control centre. Predefined messages, free text ones and direct voice conversation is normally specified. For this purpose a messaging console can be installed in the driver panel or integrated with the ticketing machine.

Control of the information panels inside and outside the bus is performed also by the vehicle OBU. It normally displays the bus line and the direction, but panels inside the bus can show also other information like the next stop, time remaining for it, and any text message the operator of the control centre would like to show (for example, to warning about a service interruption).

The vehicle OBU can be also connected to the CAN-BUS of the vehicle in case the protocol is known or to the electrical signals that go the driver panel for showing technical alarms. The information on the status of the vehicle is continuously stored and transferred at configured intervals except for alarms, which are transferred to the control centre in real-time to allow the quick reaction of the operator (for example, to send another bus ...).

The communications of the vehicle with the control centre is achieved normally by GSM/GPRS although other means such as TETRA, radio, etc. can be used. A Virtual Private Network (VPN) is created at application level to manage the communications.

Finally, other devices can be installed in the vehicle under the control of the OBU, such as ambient microphones and megaphones, so the operator in the control centre can listen to the passengers and talk directly to them.

## 2.3. Control centre

The control centre of a fleet management system is normally based on a client-server application with a powerful database behind the system, such as ORACLE, SQL or MySQL. Web-based applications can be also used, but they are not very common due to the real-time nature of the system, except for systems in which only localisation is required.

The localisation of the vehicle within the line and the assignment of every vehicle to the line is one of the most critical aspects in order to ensure the correct functioning of the fleet management system, in particular the regulation functionality that allows to establish the delay or the advance of the service as provided with respect to the original plan. This assignment is based on the vehicle position provided by the GPS receiver (and odometer if connected), the line selected by the driver in the ticketing device (which is connected to the vehicle OBU) and the assignment done in the planning information between vehicles, drivers, lines, and directions within the line. In the case of any inconsistency between the different sources, an alarm is raised to the operator in order to check the correctness of the information and correct the potential mistake (for example, the driver has erroneously selected the line in the ticketing machine, the operator has changed the bus/driver that will perform a service but it has not updated the database yet ...). This functionality informs the operator about the actual delay or advance of every individual vehicle with respect to the planned service.

The management of incidents in the provision of the service with respect to the original planning (for example, excessive delay in a line) is one the main outstanding functionalities of a fleet management system. The purpose is to categorise as much as possible all potential incident causes and solutions, so as to highlight to the operator the problems and the potential solutions, supporting the decision-making process in real-time.

The control centre shall be also responsible for the management of the message and voice communications to and from the vehicle drivers. Predefined messages should be automatically sent if configured, and messages should be classified by priority levels.

The control centre can also provide a direct interface to final users through a web system providing any kind of information about the status of the transport, including real-time maps with the positioning of the vehicles. SMS and e-mail subscription services can also be established, for example to send alerts about the status, remaining time for a vehicle to arrive at a certain stop, etc.

In the last years, the integration of the control centre application software within the environment of the transport company has gone in two directions. On the one hand, the interface with the transport planning software has become very important. The fleet management control centre receives the planned services with the vehicle and driver assignments and the schedule. In turn, it will provide the service information as it has been eventually provided, so the compliance between the original plan and the final service can be automatically checked and taken into account in the future planning. On the other hand, the control centre application software may interface with the transport company ERP software system. Information about drivers (distance covered, driving time, etc.) and vehicles (distance covered, speed profile, technical alarms, etc.) can be passed in order to determine the status of the fleet from a technical point of view and to support the management of the drivers as a human resource.

### 2.4. Passenger information system

Fleet management systems are normally complemented with a passenger information subsystem, with the main purpose to provide the users with the status of the service. Stops are equipped for this purpose with displays of LCD or LED technology. The remaining time for the next vehicle to arrive for each line is usually shown, together with other text or graphic messages; for example to inform passengers waiting at the stops about a service incident. Information boards are managed by the control centre, and they communicate with it using the same means as the vehicle: GSM/GPRS, radio, etc.

The computation of the time to arrive at the next stop is quite complicated, if it is required a sufficient accuracy and a high availability in order to demonstrate that the system is reliable and passengers can trust it. Predicting the arrival time is normally performed taking as input the current vehicle position within the line, in combination with the time required by previous vehicles to complete the same path and historic data. Genetic and neural-network algorithms can be used in order to define the optimal prediction (see for example references [1] and [3]).

## 3. Potential evolution

The fleet management systems, in the frame of the global Intelligent Transportation Systems (ITS) are still evolving, as long as new technologies become available. They will bring a better efficiency in the operations and a better service for the users. Some ideas are provided hereafter.

The communication infrastructure will evolve towards the use of UMTS mobile communications, enlarging the capability to exchange information between the different elements of the system. However, the deployment of WiMAX or iBURST broadband wireless networks will multiply approximately by a factor of 5 - 10 the data transfer rates compared with UMTS, so offering Location Based Services (LBS) for passengers will become a reality. Up to date the provision of multimedia contents in stops and in screens inside the vehicles is possible by uploading and downloading big video and music files when the vehicle is close to a Wi-Fi connection point belonging to transport communication infrastructure.

Based on the evolution of the communications, the inclusion of LCD screens within the vehicles allows the provision of contents that depend on the vehicle location, time of the day, etc. with the objective of improving the quality of the transport system, so the passengers may consider that the time spent in the public transport is not wasted but they really have some benefit. On the other hand, a wise content management will allow the public transport companies to have another source of income, because advertisements could be shown, depending on the position, time of the day, bus line, etc.

Ticketing systems may evolve in the near future towards payments based on mobile telephones. Applications are currently being developed to pay by SMS (see reference [2] for additional details), so the transport company will charge at the end of the month to a credit card to a bank account for all the received tickets. In this system, the control centre may answer with another SMS with a specific service number that will be used as justification in case of an inspection. Another potential evolution that is under investigation is the possibility to charge by detecting the presence of a person inside the bus by means of a mobile phone with bluetooth. When the person gets onto the bus, his mobile phone is detected and certain information is exchanged by means of a secured protocol to properly identify the person. Another bluetooth transaction should take place when the person will get out of the vehicle. This information is then stored in the OBU and downloaded to the central system for charging afterwards. This approach could allow charging by the exact amount of trips or kilometres that have been done, giving for more flexibility to the transport company for establishing the payment scheme. In any case, evolution of the ticketing systems will not lead in the short-term to abandon the widely used smart cards (either contact or contactless).

Although the connection between the fleet management system and the traffic one has already been implemented in certain projects, for example in order to alter the sequence of the red/green lights to favour the tramways and shorten the time required to complete the line, further integration is still possible. For example, information of the public transport vehicle speeds (when they are not at the stops) as well as from taxis could allow establishing in real-time the city congestion map that could be available to drivers by mobile internet, WiMAX or RDS to select the optimal route to arrive at their destiny.

V2X communications (including V2V) will also play a major role in the future of public transport, although they are not expected to be available in the market in the incoming years. Safety-critical applications like automatic guidance and driving of vehicles are still very immature, and they will not be available before several decades.

An important aspect that becomes increasingly important is the on-board security in public transport. Apart from the bidirectional communication between the control centre and the passengers that can be recorded, there is a trend to install video surveillance. The approach is to store in the vehicle OBU the normal video streaming and transmit in real time to the control centre the video sequencing in case of an abnormal situation. Nowadays, this is possible thanks to the UMTS mobile communications standard, but this is still only available in big agglomerations.

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