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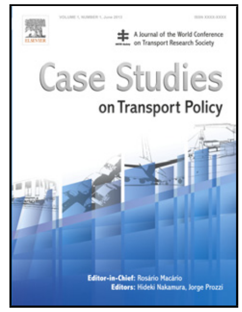


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Author: Giorgio Ambrosino Brendan Finn Saverio Gini Lorenzo Musson

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# A method to assess and plan applications of ITS technology in Public Transport services with reference to some possible case studies

Giorgio Ambrosino, GA Consultancy, giorgio.ambrosino@gaconsultancy.eu

Brendan Finn, ETTS, etts@indigo.ie

Saverio Gini, MemEx srl, saverio.gini@memexitaly.it

Lorenzo Mussone, Politecnico di Milano, ABC Department, mussone@polimi.it, corresponding author

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- Highlights ►
- ► ► ► The purpose of the paper concerns the technology and specifications for ITS applications in PT ► ITS role in the overall urban mobility management is provided with the indication of market situation ► The feasibility study and user requirements analysis are needed for the design of specifications ► ITS design must be defined according to given objectives and specific operational scenarios ► Case Studies are given to show interrelations between technology, organization and operation procedures

Abstract

The paper deals with ITS (Intelligent Transport Systems) for Public Transport (PT) services management, as key component of the wider "smart mobility" concept.

It is mainly a methodological contribution and describes the risks and motivations for which the introduction of ITS in PT could result (partially or completely) unsuccessful since some of the planned objectives are not achieved in terms of performance, cost savings and user/citizen benefits. This can be caused by an overestimation of the role and positive impacts of technology of some component and by poor user requirements analysis carried out in feasibility phase. In fact, functionalities of ITS should be defined according to the specific objectives of PT Operators or Authorities and adapted to the specific operational scenarios and organization contexts in which the system must work. It is further shown that ITS are generally made up by some subsystems and the overall performance is the result of interaction between them.

The paper firstly analyses the current technology scenario for urban mobility and transport, and underlines that the technology alone may be often insufficient to cope with transport services requirements; secondly, highlights the key role of the feasibility study and user requirements analysis for singling out the sub-systems making up the overall system and for the design of technical, functional and operational specifications for any ITS application. Finally, some relevant possible case studies in order to show composition of some ITS applications, encountered problems and how to cope them are described and discussed.

**Keywords**: Public transport, ITS, Smart Cities, User needs analysis, Feasibility study, Performance evaluation

**1.**

## 2. INTRODUCTION

In Public Transport (PT), ITS can play a primary role to guarantee a high level of performance and quality of transport services. Despite their potentials, in some cases, the introduction of Intelligent Transport Systems (ITS) is (partially or completely) unsuccessful since some desired objectives have not been achieved in terms of performance, cost savings and user/citizen benefits. This is often caused by a poor engineering project overestimating the positive impacts of technology and by the insufficient user requirements analysis carried out in the feasibility phase. Though it seems obvious, it is not completely accepted or shared that the functionalities of ITS should be defined according to given objectives of the specific Transport Operator or Authority and tailored to the specific operational scenarios and organization contexts (role of the different actors, legacy systems, transport services characteristics, etc.) in which it must work. ITS improve the quality of PT service only when supported by a proper organisation and by an effective day-by-day operation [32].
In fact, the operative and organizational scenarios for transport operations are different service by service, context by context, and they are also dependant on transport network and on the demand side which changes dynamically (day to day and within day). In fact, generally, when an ITS technology is applied to a wide range of transportation scenarios it does not guarantee by itself successful results in all of them. The application of technology, in general, requires a specific study, called feasible study since it analyzes if and how a certain application can be realized and supported by an adequate organization and operation framework (as explained better in the following sections). This is particularly true in Public Transport (PT) applications characterized by different very dynamic in time and space factors. This may look obvious or trivial but there is not yet an adequate understanding in PT applications of the needed design process that should be developed before the procurement or the realization process. Each application has its own crucial concerns, and a proper skill and tools should be prepared, together with a list of indicators and critical working ranges, in order to measure and assess the successful of the system realization and operation.
The paper is based on the long experience earned in the last two decades on the ITS field for PT, especially but non only, in the European Community and its purpose is twofold: firstly, it analyses current technology scenarios for urban mobility and transport, underlying that technology alone may be often insufficient to cope with transport service requirements; secondly, it highlights the role of the feasibility study and user requirements analysis for any ITS application, not only for designing the related technical, functional and operational specifications but also for identifying the support conditions and the operation and organization dimensions.
Section 2 reports the glossary for some most used terms in this field.
In Section 3 we present the ITS scenario, the state-of-the-art market and the weakness (both at demand and at offer side) which can affect the implementation and the operation of ITS systems [21]. At the end of this section we describe also how technologies are affected by operational issues and how these issues can impact on the achievements of the planned targets.

Section 4 analyzes the needed requirements for designing applications for transportation systems and the role of the feasibility study; in Section 5 indicators for measuring system's performances are proposed both for technical tests as for contract management; finally, in Section 6 the conclusions are drawn.
Examples are concerned mostly on the AVM (Automatic Vehicles Monitoring) system which can be considered the core component of managing and controlling PT services, guaranteeing the increase of reliability of services, the management of irregular cases with the provision of appropriate information to users and the availability of data on the weakness of operated services in order to tune the planning and to improve the effectiveness of service operation.

## 3. GLOSSARY

In this section the meaning of some terms related to ITS applications with a particular focus on PT is reported.

*AVM (Automatic Vehicle Monitoring):*
It is a means for automatically monitoring many quantities about a moving vehicle. This data, from one or more vehicles of PT, may then be collected, to monitor also the transport service.
BRT (Bus Rapid Trasport):
It is a bus-based mass transit system. A true BRT system generally has specialized design, services and infrastructure to improve system quality and remove the typical causes of delay. Sometimes described as a "surface subway", BRT aims to combine the capacity and speed of light rail or metro with the flexibility, lower cost and simplicity of a bus system

*Evaluation criteria :*
A benchmark, standard, or yardstick against which accomplishment, conformance, performance, and suitability of an alternative, activity, product, or plan, as well as of risk-reward ratio is measured.

*Failure :*
The condition or fact of not achieving the desired end or ends, or of being insufficient or falling short, or a cessation of proper functioning or performance, a decline in strength or effectiveness.

*Feasibility study :*
A Feasibility study represents the first step for analyzing and defining the objectives and the requirements of service and of Agency or operator in the case of PT services, in order to designing the main relevant functionalities and performance to be required to the system. It provides a description of the product or service, accounting statements, details of the operations and management, needs and requirements. Moreover the organization framework, support conditions and the overall costs (investments, management and maintenance) are also aspects to be faced. Generally, feasibility studies precede technical development and project implementation.
A feasibility study evaluates the project's potential for success; therefore, perceived objectivity is an important factor.

*ITS (Intelligent Transport System[s]):*

It refers to advanced ICT (information and communication technologies) applications which aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks.

*Scenario :*
It refers to an expected or actual situation or sequence of events, or processes or elements.

*Smart mobility :*
Smart Mobility aims at moving people and freight while enhancing economic, environmental and human resources by a convenient and safe multi-modal transport system, speed suitability, accessibility, management of the circulation network, and efficient use of land.

## 4. ITS SCENARIO

### 3.1 ITS framework For Urban Mobility Governance

All actions and services for mobility governance can be presently supported by a technological system, based on an ITS (Intelligent Transport Systems) platform and devices [1], [2], [29]. Possible fields of PT (Public Transport) application are many and a reference list can be found also in Ambrosino et al. [3].
All these systems are largely introduced and operating in metropolitan and urban contexts at different levels [4]. Sometimes, an appropriate strategic view for the integration between planning and operations is lacking and there is also an unclear identification of objectives and targets to be achieved through mobility governance and ITS implementation.
Despite more than two decades of very extensive European Commission supported R&D initiatives in ITS (previously only 'Information Communication Technology in Transport") and in passenger transportation, there is no comparable repository of European reports and research results yet neither in terms of solutions nor in terms of the level of fulfilment of planned targets, optimization of operational procedure and costs benefits (see www.transport-research.info). Outputs from the projects of the various Framework Programs going back to about 1996 can be found at the CORDIS website (www.cordis.eu). This is structured by projects rather than by topic, requiring the user to become first familiar with potentially relevant projects. Another ITS Toolkit has been developed by the World Bank (http://dev-worldbank.digi-interactive.co.uk).
European Case Studies on a wide range of transit topics, including ITS, are compiled by the ELTIS program (www.eltis.org) [5]. Present experience and practice of ITS applications are also described in EMBARQ database [18] for BRT services. These initiatives contribute to making evident the context-sensitive approach in the evaluation of benefits.
Inputs to standardization of technological solutions were promoted both in Europe and in US. FRAME Architecture was created to provide a common framework for the deployment of integrated and inter-operable ITS within the European Union (http://www.frame-online.net/top-menu/library/documents-and-reports/european-its-framework-architecture.html). US National ITS Architecture is published at http://www.iteris.com/itsarch/ and it also contains detailed technical information. The US ITS Joint Program Office ITS Costs Database is located at the http://www.itscosts.its.dot.gov (US ITS Joint Program Office) [6], [28]. Other information about ITS costs are in [7], [8], [9], [10], [27].

**3.2 ITS Market For Public Transport Services**

ITS applications have been a feature of public transport services for more than 30 years, particularly in urban areas, and they are widely deployed in an increasing number of countries all over the world [11].

For the Public Transport sector, the market presents many ITS products and systems that are consolidated at system or device level: besides those already cited as AVM (Automatic Vehicle Monitoring) in English literature or SAE (Système d'Aide à l'Exploitation) [12] in French version [22], [23], [25]. Despite these premises, some experiences realised in different countries and operational conditions [36] show that these products are not so flexible as to be adapted to the different requirements of the specific public transport operators and services without dedicating strong efforts in order to personalise and calibrate the different functions and operation modalities to the specific contexts. In next sections we try to explain the possible reasons of such failures through the analysis of some possible case studies.

If on the one hand it must be acknowledged that there are experienced suppliers with good products, on the other hand, in too many cases ITS providers or suppliers, active in market, are prone to the following criticisms:

- Limited capacity (or willingness) to customize their solutions/products in order to meet the true requirements and operational needs of mobility agencies and transport companies;
- Underestimation of critical issues dealing with the interaction activities with other ITS providers/suppliers (e.g. for integration of external databases, integration of ticket validators with AVM on-board terminals);
- A business approach that entails acting merely as a supplier of devices and off-the-shelf software, and not as the "Problem Solving Partner" generally required by Transport Companies, Agencies and Public Administrations.

If the potential benefits achievable through ITS are largely promoted, the same care is not carried out in making transport operators and stakeholders aware of the complexity of these systems, the real results of implementations and the support conditions necessary to operate the system (see next sections for further discussion).

Main crucial aspects are:

- Insufficiently clear identification of needs, requirements, and performance required for a system. This is often because funds and enough resources/time have not been allocated to carry out a dedicated *Feasibility Study* in advance of the procurement process;
- Insufficient awareness of the actual results, benefits and practical problems encountered by other Transport Authorities and Operators with comparable systems. This is partly due to the lack of industry-wide benchmarking of existing applications. It is also partly due to the willingness of Clients to accept the claimed successes of the ITS suppliers without performing their own market study;
- Launching procurement processes which are more oriented to technology provision, with poor estimation of the supporting services and related costs (customization, installation, travel expenses for on-site activities, software maintenance);
- Procurement processes and contract set up without proper connections to the system performance and support processes required to achieve service indicators.

### 3.3 The interactions between Technologies, Organization and Operational Levels

ITS have increasingly captured the interest of the main public agencies, vehicle manufacturing companies and mobility policy stakeholders. This is largely due to the fact that there is a common perception that the implementation of ITS can immediately achieve really significant results and a better performance: in other words, ITS enable the introduction of new customer-facing services, and, at the same time, it reduces the amount of human resources required to produce the service resulting in overall cost savings.

This perception is enforced by the decreasing cost trends of hardware solutions and by the current extended availability of telecommunications and internet platforms.

The present experience with ITS applications in a wide range of countries is that the expected or claimed performance and/or benefits are often not realised [35]. This occurs when the ITS are not accompanied by essential organizational and operational measures. Buying technology and installing it does not automatically solve problems. Technology needs to be used wisely and in an appropriate manner. Examples of possible applications and related problems are given in Section 3.

These and other client-side factors can negatively affect the start up and the management of ITS from the procurement process (P3ITS, 2011 [13]) to the implementation and operation phase

The impacts of organizations and operational procedures on the use and the exploitation of ITS solutions are very multifaceted. Therefore, we can easily state that generally there is not only one type of system capable of fitting the entire reference context.

ITS solutions must be adapted to stakeholder's specific objectives and functional requirements [15], and the design and deployment of ITS must be carefully matched to the specific PT service conditions on the individual site. Most of the functionalities - even if they look similar at a general level - can be developed in a wide range of different operative scenarios, depending on actual organization and operational procedures. That's why the percentage of successes of implementations in terms of achievement of planned objectives is variable from a city or location to another one. This obviously opens a question not only at a technical level but also at a political one.

The best way to face and manage the introduction of ITS solutions is to adopt a broader organisational view (based on a multi-criteria approach) in which improvements to business processes, structures and technology, are combined according to their strengths [14].

## 5. REQUIREMENTS ANALYSIS FOR THE DESIGN OF THE SYSTEM

### 4.1 The feasibility study

Actual practice varies very significantly from one system to another [14], [16]. The misunderstanding of correctly evaluation of the impact and the results of ITS implementation will continue until a consistent assessment of different experiences becomes available [17].

Based on the observations of worldwide experiences [35], [36], we suggest that a key underlying reason for the gap between intention and actual results is the lack of a robust feasibility analysis.

A misunderstanding in defining objectives and functionality design can be the cause of many problems (as described in section 5) in the tendering and implementation phases and of poor performance of ITS. This impact includes increased costs for procured items, additional unforeseen cost items (for both Clients and Suppliers), longer realization time, technical and operational problems and revision of scope, insufficient or imprecise testing and commissioning procedures that lead to unsatisfactory results. In such cases, there can be a deterioration in the client-supplier relationship, which is unhelpful to the Client in getting the best out of that ITS during its lifetime.

**4.2 Actions and results of the user needs analysis and feasibility study**

The objectives of feasibility analysis are reported in Figure 1. These objectives may look very simple but they require a system view and a comprehensive analysis of each component both at current and in future operating conditions. The design of system features and, above all, of its interactions with users is fundamental to achieve reliable results on future system performance.

The feasibility study must also define the milestones and the expected outcomes at each stage of implementation. This can facilitate the planning and management of the process to be implemented, within specified budget constraints and time deadlines.

System costs are closely related to the specific objectives and requirements. Users' needs affect system functionalities and the related selection of technologies and devices with different impacts on investment and operational costs (management, maintenance levels, external support services, spares) [31]. Different systems requirements lead to different architectures and selection of appropriate on-board devices (integration level, passenger counters, etc.), and communication network (radio/GPRS-UMTS/W-LAN) [19].

The main activities to be performed in a Feasibility Study for planning ITS applications are sketched in table 1. The main phases are:

- Analysis of needs and definition of requirements;
- Identification of integration requirements;
- Analysis and definition of working features;
- Estimation of costs;
- Estimation of benefits;
- Operational cost savings;
- Feasibility assessment.

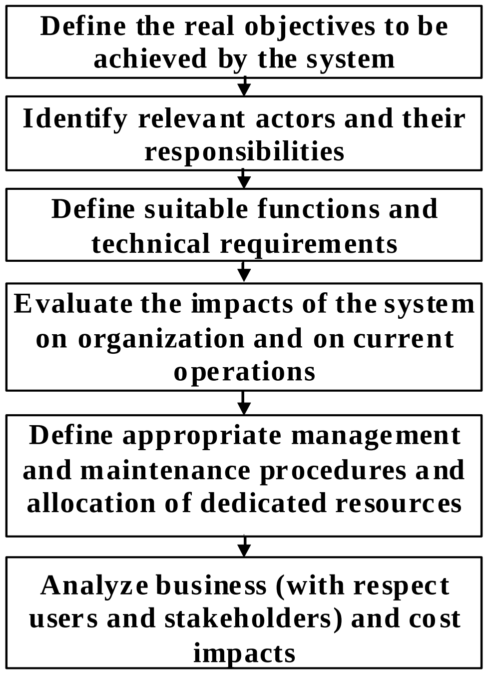


Figure 1: Flow chart of actions and analysis in feasibility studies for ITS applications.

Going further into details, in the following, we assume as reference for the sake of example a AVM system. Table 1 details the phases, related objectives, and main actions for the definition of first-level outputs of the feasibility study consisting of:

- the functional and operational specifications of the system;
- the identification of operational and organizational impacts;
- the framework elements for system implementation and operations (how, how long, how much, etc.).

At a second level, the feasibility study, starting from the outputs of Table 1, must lead to the achievement of a detailed estimation of costs/benefits.

## 6. SOME POSSIBLE CASE STUDIES OF ITS APPLICATIONS IN PUBLIC TRANSPORT

Previous sections show that objectives and system devices, system functionalities and operational procedures for an ITS application are strictly interrelated. In this section we provide some example of which indicators can be used to measure system performances. These indicators are mainly relating to AVM system but also some other ITS are involved. These examples are presented under a quite general approach in order to be easily focused both to BRT systems [16], [24] and to other PT applications; their analysis is limited to ITS aspects but this obviously does not mean that many other designing aspects could have to be taken into consideration (e.g. mechanical, civil engineering, electrical concerns related to the specific transport system).
Generally, ITS systems are complex since involve many subsystems. For this reason we can think to study (or predict) overall performance by applying system theory starting from the performance of each subsystem. First step of this approach is the decomposition in as many

subsystems as needed. Unfortunately, this approach can be unsuccessful when performance are not always constant in time, that is, they depend on some factors not easy to control though they were limited in time control (i.e. the GPRS/UMTS communications, GPS signal in specific urban roads) or dependant on operational/management procedure rather than technical failures. When uncontrolled situations may be many, overall performance should be tested on field in order to take into consideration all possible combinations of failures or malfunctioning.

The list of indicators and their description is reported in table 2; acceptable ranges are also inserted and refer to satisfactory working conditions but, of course, they could be changed (lowering or increasing the limits) by system managers. It is worth stressing that these ranges are drawn on the basis of the authors' experience and aim at defining working conditions in which failures must be, in any case, random and, when they occurred, do not compromise the overall performance.

In table 3 a resume of case studies with related indicators is reported.

In any case, in order to achieve a high rating for the above mentioned indicators, it is needed to guarantee at least the following background working conditions, and precisely:

- a proper description of the PT network, in terms of accuracy of arc lengths, bus stops and traffic light positions;
- presence of operators in the control centre for monitoring service operation and situation;
- well organised management structure for an efficient maintenance (on board devices, on street infrastructures, communication devices and central room components);
- high reliability of communication network between on board systems and control centre in order to guarantee a real time service for field condition update.

1) *Dynamic information at bus station/stop*

Dynamic information at bus station/stop can be defined as a primary objective of an AVM installation (TCRP, 2003 [20]). This kind of objective focuses on the display of information to users. However, the Transport Operator should also be able to define an effective and precise operational procedure (both at the Control Centre and at driver level) for managing irregular service incidents during operation - otherwise information provided by panels would probably be wrong (or would just show the scheduled times).

It is not feasible to provide reliable dynamic information on different dissemination channels (panels, web/SMS, IVR, etc.) if there is not an effective fleet control. The functional performance of the AVM system can be suitable for estimating the arrival time of vehicles when no disruption occurs (failure of vehicles, accidents, etc.): in these cases the information displayed by panels is correct if the system runs properly. But when the regularity of the service falls below a certain threshold (e.g. due to high congestion or demand) even the best system on the market may not be adequate and fail to give correct estimations: although the system incorporates functions to deal with these cases, it might be necessary to carry out appropriate manual operations to make these functions work properly. If these operations are not guaranteed by the Transport Operators' staff, information displayed will be incorrect (and it must be stressed this is not due to a system incongruence). If this has not been understood and included in the design from the beginning, it is likely that the planned performance will fall under par.

From the specific point of view of factors that affect system performance of the above mentioned functions, they can be monitored by controlling the following indicators:

- **availability rate of on board system** (rate of event identification, ie.bus stops recognised by on board terminal);

- **availability rate of control centre** (bus monitoring rate, identification rate of rides).
- **precision of time estimation of bus stop**;
- **accuracy of bus location**;
- **availability rate of info devices** (at bus stop/terminal);

2) *Information Systems*

A second case concerns the range of options available for an information system [30]. Large dynamic panels at bus terminals/stations have high visibility and may be attractive to the project promoters as a manifestation of positive change. However, they represent a higher investment and on-going maintenance costs. “Smart technologies” generally involve very low investment costs, since they harness existing internet and telecommunication platforms, and the passengers’ own devices.

Often transport operators and public authorities are suspicious of the activation of road info-panels because of the risk of providing incorrect arrival times during irregular service conditions: such as diversions, modifications to the planned routing carried out during the service operation, vehicle breakdowns, etc., when AVM functions and operational procedures are not able to guarantee the application of appropriate action.

Panels on the road are seen as a source of possible negative income to the company or city image since the information is visible and accessible to everyone (the citizens besides the transport users). On the other hand, SMS/web technologies are incorrectly seen as “reduced risk and low impact” solutions for the image of Transport Companies since mobile applications must be searched for and downloaded on the market by the same users. Mobile applications make it possible to save costs for installation of panels on the road or under the shelters but, from the functional and operational point of view, this is even more critical since, after accessing the mobile application, users can display the arrival time for all the bus stops and check for their correctness.

From the organizational point of view, a real-time AVM system able to provide an effective control capability during the daily service operation and the provision of real time user information [21], [33], requires the allocation of dedicated human resources. This effort can be day-long, or restricted to peak service times, at pull-in/pull-out times and/or for exceptional demand. Where budget and cost requirements justify it, this task can be carried out with a well-equipped control centre (workstation, monitors/video-wall, voice connection, etc.). A low-cost alternative could consist of a new browser platform using web server-client solutions over a LAN/WAN/VPN connection (even from other locations e.g. maintenance office, secondary premises).

The first option leads to a “concentrated” control scheme. It requires higher investment costs and it is more suitable for metropolitan/large urban areas, complex networks, integrated transport services (e.g. a BRT trunk/feeder network).

The second option is more flexible and aims at minimizing operational costs (avoiding dedicated resources). It creates a “distributed” control scheme requiring targeted operational procedure and timely cooperation between responsible entities/offices. This is particularly suitable for medium size urban areas, or corridors connecting peripheral areas. The technical design deals with the requirement of appropriate technical performance of communication networks (such as virtual remote network bandwidth). The choice between the two options may depend on the organization structure of the Transit Operators.

If the primary objective of the AVM is the certification of service performance (reliability, kilometres travelled, operating time, travelling time, delays at main terminal/stations), then an off-line service might be enough. This could use data collection based on on-board devices

with back-office post-event analysis and reporting. In this scenario, control and fleet management functions can be reduced to the main relevant event (response to vehicle breakdown, adaptation of the service to daily events). The organizational structure and allocated staff would be reduced to these functions. Real-data monitoring and user information are not possible under these conditions.
From the specific point of view of factors that affect system performance of the above mentioned functions, they can be monitored by controlling the following indicators:

- **availability rate of on board system** (rate of event identification, i.e. bus stops recognised by on board terminal);
- **availability rate of control centre** (bus monitoring rate, identification rate of rides).

3) *Definition of the degree of integration of control level*
Another relevant case is the definition of the degree of integration of control levels and the allocation of responsibility in presence of AVM, call centres for users, video-surveillance. In this case, depending on the organizational structure, different operational procedures must be defined if the activities are concentrated on AVM control centre staff or allocated to various actors (control centre staff, users contact points, police stations).
From the system point of view this is not dependent on system performance but on the type of functionalities needed or required.
4) *Provision of on-board info on the bus*
A fourth case is the provision of on-board information on buses during trips (i.e. the visualization and announcement of the next stops, line indicators, audio for impaired people, etc.). This kind of functionality requires good “line-matching” positioning on route to be provided by on-board devices: irregular cases, such as routing modifications, diversions, service interruption due to vehicle breakdowns, must be managed also at on-board level through driver notifications or event communication from a Central software system.
From the specific point of view of factors that affect system performance of the above mentioned functions, they can be monitored by controlling the following indicators:

- **availability rate of on board system** (rate of event identification, i.e. bus stops recognised by on board terminal);
- **availability rate of control centre** (bus monitoring rate, identification rate of rides).
- **availability rate of on board info devices**.

5) *Priority measures for public vehicles*
A fifth case is provided by the implementation of priority measures for public vehicles [26]. The definition of priority strategies depends on the objectives identified in feasibility analyses and on the results of simulated impacts on the whole urban traffic: priority can be given to all public vehicles or only to delayed ones, to all the operated lines or only to the main axes, with various levels of impact on private flows. The definition of priority strategies must be defined by weighting appropriately the objective of improving public transport performance compared to the simultaneous perturbation caused to private traffic flows.
From the specific point of view of factors that affect system performance of the above mentioned functions, they can be monitored by controlling the following indicators:

- **availability rate of on board system** (rate of event identification, i.e. bus stops recognised by on board terminal);
- **availability rate of control centre** (bus monitoring rate, identification rate of rides).
- **accuracy of bus location**;

The accuracy of the priority strategy is strongly dependent on the performance of the other ITS system dedicated to the traffic light coordination (urban Traffic Control).
6) *e-Ticketing system*

A sixth case can be taken from e-ticketing system [28]. A relevant issue to be analysed is the possible requirement of an integrated ticket between BRT trunk and feeder services. This operational requirement, among others, leads to different possible scenarios that must be detailed such as the specifications of clear functions/procedures which are strictly dependant on accounting procedures and income management.
From the specific point of view of factors that affect system performance of the above mentioned functions, they can be monitored by controlling the following indicators:

- **availability rate of on board system** (rate of event identification, i.e. bus stops recognised by on board terminal);
- **availability rate of control centre** (bus monitoring rate, identification rate of rides).
- **accuracy of bus location** (in the case of fare zones ).

7) *Provision of info-mobility services*
A further case is the provision of info-mobility services. Real-time provision of bus arrival times requires:

- the adoption of controlling procedures (under a “concentrated” or “distributed” scheme) and day-to-day management of appropriate operations for irregular cases;
- buses operating the service with faulty on-board devices or no system installed generate incorrect or incomplete information (this highlights the relevance of an appropriate management of maintenance procedure: such as diagnostics, on-site intervention);
- a high quality of bus service performance guaranteed by the responsiveness of AVM systems, depending on functional solutions to operational requirements of the operator;
- a strong regulation (and monitoring) of main road infrastructures, that is, road lanes;
- a real-time management of events on the network.

Moving towards real-time information provided on web applications or via SMS, the impacts of operations and management of services is even more relevant. Large dynamic panels at bus terminals or stations have high visibility and may be attractive to project promoters as representing a manifestation of positive change. However, they have higher investment costs and ongoing maintenance costs. “Smart technologies”, on the other hand, involve very low investment costs.

**Correct* is obviously a vague term but, in this context, it means that the system or the device under examination is working for a time longer than a set threshold.

From the specific point of view of factors that affect system performance of the above mentioned functions, they can be monitored by controlling the following indicators:

- **availability rate of on board system** (rate of event identification, i.e. bus stops recognised by on board terminal);
- **availability rate of control centre** (bus monitoring rate, identification rate of rides).
- **precision of bus arrival estimation at bus stops**.

From the technical and operational point of view the above mentioned target values of performance indicators are built according to following definitions:

– **indexes of system availability**: they are related to the maximum time length accepted by the contracting body for restoring the full operation of the system in case of breakdown or malfunction (impacting the whole functionality of the system or, at least, some parts of it) and to the maximum number of breakdown events accepted by the contracting body over a certain working interval (generally one month). Obviously, the target value of these indexes should be even more higher for such components as control centre or panels installed at bus stops, whose breakdown implies directly an evident worsening of system functionalities or it is immediately visible to customers;

– **other indexes**: the target values are closely depending on fleet dimension and service conditions (number of lines and daily trips); for instance, in the case of AVM/SAE performances, they are related to the average number of irregular cases daily managed in service operation.

In the proposed approach the target value represents the level of compliance of the implemented or operated system to the technical specifications defined in the contract (a lower value means a more unsatisfactory situation for contracting body). Once defined the target value for each index they can be compared with the values achieved on field. Two cases can occur:

- small differences (less than or equal to 10% of the target value ) may not affect so much system operation; nevertheless, the achievement of lower performances compared to the target value impacts on contractual side (penalties, necessity to repeat tests, postponement of final acceptance of the system and/or duration of the warranty period until target values are achieved). System is enough effective to be operated without relevant problems even if the causes of lack of achievement of target value must anyway be identified and solved. Action plan for improving indexes values must be defined;
- large differences (more than 10% of the target value) mean that the system/service cannot be operated properly and contractual consequences are more relevant (not acceptance of the system, necessity to repeat tests starting from the functional ones or, in the worst case, resolution of the contract).

The measure of these index values related to system functionalities should be carried out by a set of performance test properly defined also in terms of on field procedures.

From the contractual point of view the target value of performance indexes allows to measure the reliability of system functionalities over time and to verify whether the level of maintenance (or warranty) is appropriate to guarantee the overall operation. Moreover, the target values can be used in the contract in order to carry out payments to the system provider in presence of the effective certification of target achievements both during implementation phase (certification test) and during post maintenance or operation phase. In order to define which level the system complies with the defined target values of performance indexes, after the achieved value for each indicator is calculated, a global value can be then calculated using a vector of weights depending on the relevance of each indicator (in order to carry out a a multi-criteria evaluation).

**7.**

## 8. CONCLUSIONS

The paper analyzes the state of applications of ITS in PT services recognizing that many of these systems are largely introduced and operating in metropolitan and urban contexts at different levels [14]. What is sometimes lacking is an appropriate strategic view of the integration between planning and operations and an unclear identification of objectives and targets to be achieved. Consolidated products are not likely to be as flexible as needed or cannot adapt functions and operational modes to the various requirements of the specific public transport operators and stakeholders.

The main weaknesses are due to:

- Limited capacity (or willingness) to customize solutions or products to meet the true requirements and operational needs of mobility agencies and transport companies;
- Underestimation of critical issues dealing with the interaction activities with other ITS providers or suppliers;
- The business approach of acting just as a supplier of hardware and off-the-shelf software.

Main crucial aspects are:

- Insufficiently clear identification of needs, requirements, and performance required for a system;
- Insufficient awareness of the actual results, benefits, and practical problems encountered by other Transport Authorities and Operators with comparable systems;
- Launching procurement processes which are more oriented to the provision of technology;
- Procurement processes and contracts set up without proper connections to system performance and support processes required to achieve service indicators.

To overcome the above mentioned criticisms it is strongly recommended to carry out an in-depth *feasibility study* of the system to be implemented. The feasibility study is the opportunity for laying down and specifying the real requirements and objectives to be achieved, for coming up with solutions, and for designing system functionality. Not surprisingly, when the technical systems are designed to respond to the well-thought out and detailed requirements of the transit agencies, they have a far higher chance of success. The feasibility study is also an opportunity for all internal and external stakeholders to understand ITS and their long-term potential.

The qualification process developed by the feasibility study is also capable of developing technical profiles to support the tendering process and the contracting phase from the technical point of view and the implementation phase for the monitoring of the technical compliance of the system to contractual specifications and the management of contract prescriptions.

The given case studies of typical ITS applications for PT show what difficulties must be faced, how they can be overcome by a proper feasibility study, and how to measure overall performance.

Future developments of this paper could concern an extension of the described approach to all types of ITS applications. Also the way the indexes can be calculated and the following impact on evaluation could deserve further research since it affects the real robustness of the whole approach.

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Table 1(first part): List of phases, objectives and activities in feasibility studies for ITS.

| Phase | Objectives | Related details |
|---|---|---|
| **Analysis of needs and definition of** | Reference context analysis. | Service typology and dimensions; Contract service performances. |
| | Identification of involved actors and | Statutory Authority managing the |

| | | |
|---|---|---|
| **requirements** | related objectives to be achieved by the system for each of them. | service contract;<br>Knowledge of all technical features. |
| | Organization and operation procedure analysis. | Service control and monitoring;<br>Regulation measures at headquarters/on the road;<br>Vehicles management at depots and maintenance procedures. |
| | Technological infrastructure analysis;<br>Existing mobile network performance and coverage;<br>Existing operational software packages for integration of implemented ITS. | Communication network between different sites. |
| **Identification of integration requirements** | Integration with existing vehicle devices. | Direction panels;<br>CAN bus for operation and diagnostic signals such as fuel, brake, air. |
| | Integration with other ITS systems at on-board and at control centre level. | Electronic fare system;<br>Traffic light priority;<br>On board info;<br>Video cameras on board. |
| | Integration with company databases/systems and flow data with Statutory Authority. | Service data such as travelling time along routes and route segments;<br>Travelled kilometres during the operation in/out of service;<br>Certification of services performance;<br>In fare system for reporting transported passengers;<br>Incomes; Sales volumes. |
| **Analysis and definition of working features** | Functional, technical and operational specifications for each component and sub-system. | |
| | Modifications of existing operational procedures when the system is in operation;<br>Allocation of responsibility for system management and operation. | |
| | Implementation plan | |
| | Maintenance process and related operational procedures. | |
| | Investment/operational costs. | |
| | Modalities for system purchasing and possible co-financing sources. | Service or direct investments. |

Table 2: List of indicators, their formulation and range of admitted variation.

| Indicator | Analytical Definition | Range of Acceptable working conditions |
|---|---|---|

| | | |
|---|---|---|
| On board terminal availability | $$F_B = \frac{X_{on}}{N - X_{off} - X_g}$$ $X_{on}$ = sum of working on-board systems<br>$X_{off}$ = sum of not working on-board systems<br>$X_g$ = sum of on-board systems installed on buses on maintenance<br>N =total number of on-board systems installed and in store | 99.0-100%<br>(on a daily basis) |
| Control centre availability | $$D_C = \frac{T_{on}}{T_{tot}}$$ $T_{on}$ = sum of intervals of correct* working of the control centre<br>$T_{tot}$ = sum of intervals of required activity of the control centre | 99.0-100%<br>(on a daily basis) |
| Availability of on-board info devices | $$F_D = \frac{X_{on}}{N - X_{off}}$$ N = number of devices (displays, board terminal, load speakers, ticket machines) installed on-board<br>$X_{on}$ = sum of devices real working<br>$X_{off}$ = sum of devices not working | 95.0-100%<br>(on a daily basis) |
| Availability of info devices at bus stops/terminal | $$F_S = \frac{X_{on}}{N - X_{off}}$$ N = number of devices (poles, VMS, sign platforms) installed at stops/terminals<br>$X_{on}$ = sum of devices real working<br>$X_{off}$ = sum of devices not working | 99.0-100%<br>(on a daily basis) |
| Precision of bus arrival time estimation at bus stop | $$P_P = \frac{\Pr ev_{on}}{\Pr ev_{tot}}$$ $\Pr ev_{on}$ = sum of the number of correct* estimations of arrival/departure times at bus stops in a set interval<br>$\Pr ev_{tot}$ = total number of measurements in a set interval | 98.0-100%<br>(on a daily basis) |
| Accuracy of bus location | $$P_L = \frac{LOC_{on}}{LOC_{tot}}$$ $LOC_{on}$ = sum of the number of measurements in a set time interval for which the bus is accurately localized<br>$LOC_{tot}$ = total number of measures in a set time interval | 98.0-100%<br>(on a daily basis) |

Table 3: List of indicators for the proposed examples of ITS applications.

| Case study | Indicators |
|---|---|
| **1 Dynamic information at bus station/stop** | On-board terminal availability |
| | Control centre availability |
| | Precision of time estimation of bus stop |
| | Accuracy of bus location |
| | Availability of info devices at bus stops/terminal |
| | Reliability of GPRS/UMTS communication network between on-board Systems and AVM Control Centre |
| **2 Information Systems** | On-board terminal availability |
| | Control centre availability |
| **3 Definition of the degree of integration of control level** | Specific objective of system managers |
| **4 Provision of on-board info on the bus** | On-board terminal availability |
| | Control centre availability |
| | Availability rate of on-board info devices |
| **5 Priority measures for public vehicles** | On-board terminal availability |
| | Control centre availability |
| | Accuracy of bus location |
| **6 e-Ticketing system** | On-board terminal availability |
| | Control centre availability |
| | Accuracy of bus location |
| **7 Provision of info-mobility services** | On-board terminal availability |
| | Control centre availability |
| | Precision of time estimation of bus stop |

9.