EVALUATION OF AN OPEN INTELLIGENT IN-VEHICLE TERMINAL FOR REGULAR AND FLEXIBLE PUBLIC TRANSPORT SERVICES

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SUMMARY

The INVETE project, which is co-sponsored by the IST-programme of the European Commission, has as its main aim to develop and demonstrate an intelligent in-vehicle terminal (IVT) for both flexible (DRT, shared taxi) and regular (line-based) collective transport. Two different types of terminals have been developed: a terminal with a simple interface for regular public transport and a terminal with a TFT-LCD touchscreen interface for DRT services. Twenty terminals have been prototyped and are evaluated in different services in Finland and Italy. In Florence, Italy and Kuopio, Finland, the terminal is demonstrated for DRT services, and in Tampere, Finland, for regular public transport. This paper describes the open terminal, the results of the validation in the different test sites and how the terminal can be implemented.

INTRODUCTION

The in-vehicle terminal is the main technological on-board element of an Automatic Vehicle Monitoring (AVM) system. Through AVM systems the operator can monitor and improve the quality of the transport service provided. The in-vehicle terminal offers real-time communication between driver and control centre, and its user interface allows the driver to operate the service efficiently. Previous R&D projects on European level, such as SAMPO and SAMPLUS, have indicated that there is a need for an in-vehicle terminal (IVT) for flexible collective transport services, such as Demand Responsive Transport (DRT).

An open and modular terminal, which can be easily updated and adapted to the future needs of the operator, is desired. An IVT, which is not only designed for DRT but also for regular public transport, allows operators and software developers to use the same platform for all fleet vehicles and to use the same vehicle for different transport services. Regarding the economics, an open IVT makes both maintenance and service development and deployment easier, and hence the cost of an IVT and the related services can be decreased.

The main objective of the INVETE project is to develop and demonstrate a *modular*, *multi-application* in-vehicle terminal, which is able to support a variety of functionalities for both flexible and regular collective transport services.

OVERVIEW OF USER NEEDS

USER NEEDS RELATED TO THE TRANSPORT SERVICES

An in-vehicle terminal for public transport serves two main goals: for the driver, it allows to manage the transport service; for the control centre, it gives access to information on transport service operation. The main concern of the operator is to operate the services cost-effectively and according to the schedules. The IVT should be easily maintainable, updatable and interoperable with other in-vehicle services. The main concern of the drivers is to drive safely, to realise the services according to the schedule and to be informed on the service to be realised and on changes in the service.

Regular public transport terminals should have a simple user interface, which consists of an advance/behind status indicator, buttons to send precoded messages, and a display for text messages. AVL (Automatic Vehicle Location) systems, which are used to monitor collective transport fleets, impose stringent requirements on the communication with the control centre. The vehicle should send location and status data in a short predetermined time interval, to enhance a/o the accuracy of the calculations of predicted arrival times shown at bus stop signs.

In flexible collective transport systems, a user interface with extensive graphics is desired for representing maps, if the destination is unfamiliar to the driver. Since the trip plan is more complex and more dynamic, more information has to be displayed and the driver is working more interactively with the user interface. The location information is less frequently transmitted, but the messages exchanged with the control centre on e.g. the next trip plan or changes in the current trip make the communication heavier than in the AVL case.

NEED FOR AN OPEN PLATFORM

Operators are in need of an open platform for in-vehicle terminals, in order to solve problems related to life cycle support and non compatible ITS environments.

When the first generation of public transport monitoring systems has to be updated, operators often find that the original providers either do not exist anymore or do not anymore support the product, so that the only possibility is to change the whole system. There is therefore a need for an open system, which ensures the possibility to add new functionalities during the lifetime of the product.

In a deregulated environment, public transport operators provide the services on a contract basis, which may be one year or shorter. Public transport operators optimise the use of their fleet, so the same vehicle can be used in different regions with different ITS environments. This also asks for an open system, which can be easily adapted to the needs of the different operational environments.

Also the needs of the developers have to be taken into account: they need a terminal, which can be tailored easily to meet the requirements of his clients, which offers an open platform for development, and allows to use commercial development tools and third-party software.

OPEN IN-VEHICLE TERMINAL CONCEPT

The INVETE in-vehicle terminal consists of two modules: the Base Module, which owns all interfaces, and the Application Module, which has the interface to the driver (1). In this way, the conflicting set of requirements for regular public transport (real-time communication and stability) and for DRT services (graphical user interface and flexible programming possibilities) is taken into account.

The **Base Service Module** (BSM) features a real-time operating system and hosts the services for positioning and communication, both with external systems (private radio network, GSM, short-range communications) and with in-vehicle devices (in-vehicle network, microphones, loudspeakers, silent alarm button, odometer...). The Base Module is modular unit, using the PC104 architecture, and can be built into various combinations. The flexible structure allows updatability of existing elements and adding of new elements, so the Base Module will meet the long lifetime demand.

The **Application Service Module** (ASM) owns all Human Interface devices (display, keyboard, other pointing devices). The ASM is tailored towards the needs of the users and services. For **flexible transport services**, the ASM has a TFT-LCD touch screen, and its own CPU and a widely used commercial operating system, with advanced graphical possibilities. The CPU exchanges data with the BSM via an **Ethernet** connection using TCP/IP protocol. For **Regular public transport (AVL) services,** the ASM has only a simple display, some buttons and a controller, which is hosted by the BSM via a serial RS485 communication, forming in this way an affordable IVT.

The modularity of the INVETE platform at software level is achieved by using socket-based services (2). For the communication between the services in the terminal and between the different modules, a protocol has been developed which is based on TCP/IP (3). This open and public IVT protocol gives the different services on the IVT access to the information generated by the other services on both modules in a manner independent of the way the service is implemented.

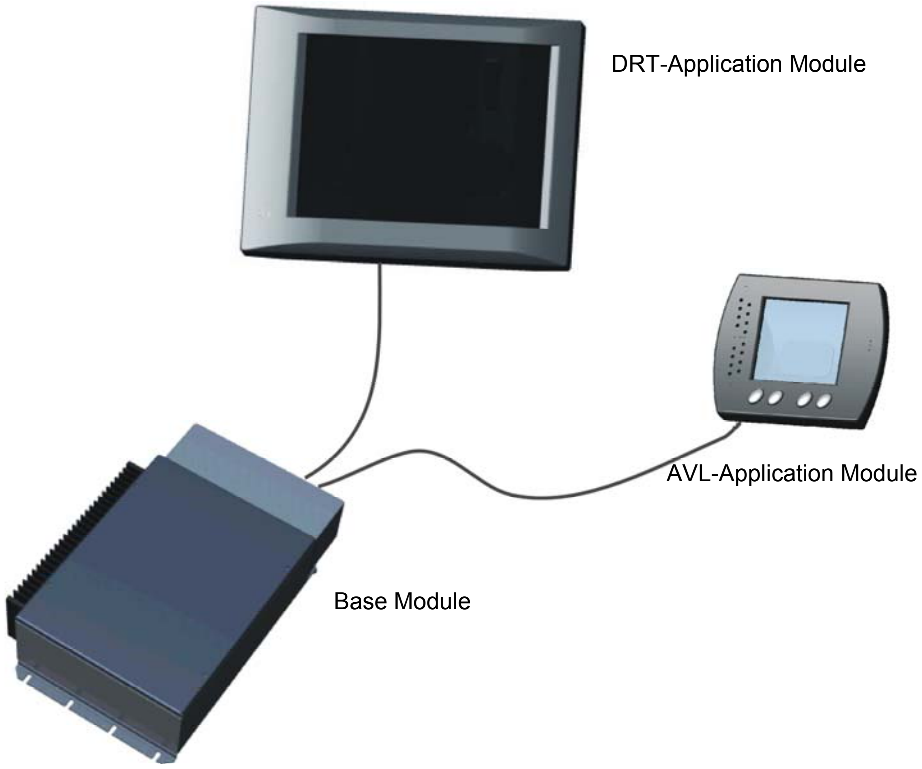

Figure 1: INVETE Terminal

IN-VEHICLE TERMINAL DEMONSTRATION

More than 20 IVT's are demonstrated in real operating conditions at different test sites in Finland and Italy from winter 2001 onwards. In Finland, the terminals are installed in regular long-distance buses operating between Tampere both Helsinki centre and Helsinki Airport. As communication, the terminal uses a Private Radio Network in the urban areas of Tampere and Helsinki, and GSM outside the coverage of the private network. Through the terminal, the control centre is informed on the position of the vehicle. The driver receives information on the next destination and on the adherence to the schedule.

DRT services are demonstrated in Kuopio, Finland and in Florence, Italy. Both sites use the in-vehicle terminal with 10" TFT-LCD touch screen. The interface to the driver differs: in Kuopio a simple textual-based user interface has been developed; in Italy the interface also supports showing the real-time position of the vehicle on a map of the network. In Kuopio, 3 terminals are installed in service buses and 1 terminal is installed in a maxi-taxi. In Florence, in total 8 terminals are installed in two different minibuses in two different services.

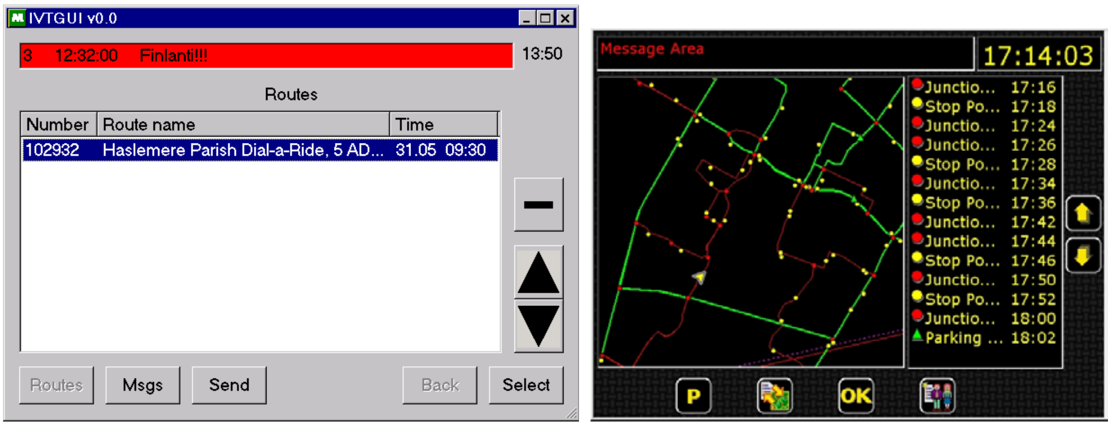

Figure 2: User interface for the DRT applications demonstrated in Finland (left) and in Italy (right)

VALIDATION OF THE TERMINAL AND THE SERVICES

Validation includes the technical performance, user acceptance, impact on service provision, and cost benefit assessment. Also the architecture is assessed, and the possibilities to use the terminal in other environments. The terminals, which were installed in the vehicles, worked without major problems during the demonstration period. The drivers and operators were satisfied with the terminals.

VALIDATION RESULTS FOR THE DRT SERVICES IN FLORENCE

The terminals are operated in two different DRT services, one in Campi Bisenzio and the other in Scandicci. In total 8 terminals were installed: in 6 vehicles in Campi Bisenzio and in 2 vehicles in Scandicci. During the test period, the in-vehicle terminals worked in the Florence test sites without major problems. All the drivers, who were operating the vehicles, were very satisfied with the terminal. The only negative comment was on the placement of the prototype terminal, since the prototype installed on some of the vehicles was not well placed because of some impediments to the view of the screen. Also the operators were very satisfied. The only criticism of the control room personnel was related to the tracking functionality, since drivers do not always inform if they take deviate from the prescribed route to avoid a traffic jam or accident, which may complicate handling of customer bookings. Compared to the results of the test site in Kuopio, the results are more positive, which is mainly due to the larger technological step, since no terminal was previously in use.

The main benefits associated with the use of the INVETE terminal in the test sites of Florence has accrued from the simplification and speeding up of a number of service operations performed by the drivers and the TDC team. Compared to the situation without INVETE terminal, consistent time savings for drivers and TDC operators have been experienced for the "start/end of service" procedures (dispatching the vehicle's daily work schedule to the driver, registering operational data at the end of the service), as well as for trip change procedures (adding/deleting pick-ups and/or drop-offs to the vehicle schedule during the service, route changes for traffic congestion or disruptions caused by accidents and roadwork). On the whole the estimated time savings per day coming from the use of the IVT in the two Florence test sites amount to about 2% for the drivers and 2.5% for the operators. These time savings are likely to result in increased labour productivity for the transit agency.

The use of the IVT in Florence DRT applications has also taken reductions in the number of delayed trips due to faster communication and visualisation of the trip schedule and of the main traffic disruptions, as well as reductions in the number of failed trips and in trip time especially when the driver don't know the address of the requested pick-up/drop-off locations. Thanks to these reductions the INVETE terminal is expected on the one hand to enhance the travel time reliability that is an important factor for improving the customer satisfaction and the service quality, on the other hand to positively influence the DRT service productivity by increasing the number of trips that can be accommodated per vehicle-hour. Another significant benefit brought by the IVT is an improved feeling of safety for drivers and passengers. The use of pre-coded messages (accident, vehicle breakdown, medical assistance, etc) allows immediate location of the vehicle and appropriate response by dispatchers, who can then notify transit agency security, local law enforcement officers or medical services as necessary. In addition to perceived safety improvements for drivers and passengers, real time communication between the driver and the control centre aids the transit agency in reducing drivers-hours and passenger-hours of delay caused by emergency situations.

An objective and conservative economic and financial assessment has been carried out in the test sites of Florence, where only the more predictable and quantifiable monetary benefits associated with the INVETE terminals have been estimated. This analysis, based on conservative and cautious assumptions and considering a 5 years lifetime of the INVETE device, has shown that the net benefits broadly exceed the related costs. This analysis did not take some of the major benefits of the terminal in account, such as the openness and the possibility to update and integrate new devices.

VALIDATION RESULTS FOR KUOPIO

The INVETE terminals have been installed on four vehicles in a DRT service in Kuopio: on 3 service buses and in a maxi-taxi. Originally, the fourth in-vehicle terminal was planned to be installed in a normal taxi (Peugeot 405) instead of in the third service bus, but the terminal - which was designed towards the requirements of minibuses - was too large for this vehicle. In Kuopio, an in-vehicle terminal (Aplicom) was already in use, and was not removed from the vehicle, and could be used by the drivers if required. Hence, also the operation of a DRT service with different on-board terminals was demonstrated. The drivers although used the INVETE terminal most of the time. The INVETE terminals functioned without major problems. The number of communications per day is much smaller than in Florence, and differs for service buses and maxi-taxis: since maxi-taxis have smaller capacity, they have more trip plans, resulting in a larger number of communications (of trip plans), but with smaller size. The drivers were satisfied with the terminal, and found it better than the former terminal. Due to the modular structure and the multi-processing capabilities of the terminal, the user-interface could be improved.

Since the replacement of the terminal did not cause any change in the procedures, the direct benefit for the users is not so large, and lays mainly in the modular structure of the terminal, which allows it to implement new services and integrate new devices more easily. The INVETE terminal has a wireless maintenance feature, which makes maintenance much easier - avoiding travel costs - and allows to increase customer satisfaction due to a faster reaction in case of software or database problems. The possibility to use commercial development tools and the modular and open structure of the terminal allow decreasing development costs considerably.

IMPLEMENTATION ASPECTS

When planning monitoring systems for regular public transport services or DRT services, the whole life cycle of the monitoring system or service should be taken into account. The system should be easily adaptable if the service concept or size changes if new applications are desired, such as real-time passenger information on-board or video surveillance to increase safety. It is therefore advisable to include in the call for tender, or in the selection procedure, criteria for assessing the following aspects:

- **modularity.** The roadside or communication network infrastructure can change during the lifetime of the product, forcing the operators to perform substantial investments. During the life cycle of the terminal the vehicle may be moved to another environment (city, region), which uses different communication methods. The vehicle could also be used in another service, dependent on the needs of the moment (e.g. DRT service instead of regular line).

- **openness.** During the life cycle of the product, the system provider may shut down the production of the terminal, so that a new manufacturer has to be sought. By using an open system such as the INVETE platform, it is possible to replace the device with a device based on the same protocols and interfaces.

- **compliancy to standards and possibilities to integrate the terminal with current and future on-board devices.** The EN13149-6 prestandard, will become a standard in the coming years, and new on-board devices will have to be compatible with this standard.

- **updatability.** The possibility to update the software wirelessly or to upgrade the terminal without major work at the terminal and at the control centre.

When updating a current monitoring system, the INVETE platform provides a path to make the in-vehicle infrastructure more simple and modular. Starting on a roadmap of future technologies and devices that will be implemented, different levels in the implementation of the INVETE terminal can be defined, e.g. only application module; implementation of part of the interfacing and communication functionalities in a Base Module. The identification of the different levels of functions requires finding a balance between the needs of new functions to be implemented and the lifetime of existing devices. Due to the modular structure of the INVETE terminal and its interoperability with future standard in-vehicle network architectures (EN 13149-6), the architecture of the monitoring system can be simplified, when adding new functionalities. Depending of the level of implementation, the software on the Base Model or Application Modules developed for the INVETE test sites can be reused with minor or more modifications. If the Base Module isn't implemented, some additional software needs to be developed, or for the ASM (DRT services), or for the current processing unit in the AVL vehicles.

An AVM system is a complex system, and a small operator has not always the possibility to maintain such a system. The operator is therefore demanding party for an "AVM Global Service", in which the System integrator takes not only care of the system maintenance and assures that is properly working, but also of the investment costs, so that they can concentrate on operating the service.

BENEFITS OF THE OPEN PLATFORM

The benefits of the open terminal platform to the different actors are:

For the **dispatching,** it provides a standardised way to communicate with the driver, independent of the selection of the terminal hardware. So, for a fleet of different operators, the communication from the dispatching with the driver happens always in a similar way.

For the **transport operator,** it gives the possibility to use the same platform for all the vehicles of the fleet (and hence to select the transport vehicle in function of the current needs). The open platform also gives the possibility to customise the terminal to the different requirements of different authorities. Since the in-vehicle terminal platform is based on an open protocol and set of specifications, it allows selecting between different terminal manufacturers, which use the IVT protocol (independent of the software provider).

For the **application developers,** the use of the IVT platform makes the development of software easier through the use of open interfaces, and the software can be developed independent of the hardware manufacturer. The platform eases customising the application software to the needs of the customers.

CONCLUSIONS

The INVETE project has developed and demonstrated an intelligent in-vehicle terminal for flexible and regular collective transport services. Through real-time communication, positioning, and in-vehicle network technologies, the terminal improves the perceived level of safety of the driver (by providing real-time contact with the control centre) and reduces the workload of the driver (by allowing to combine different user-interfaces in one interface).

The validation results have also demonstrated that the INVETE terminal is a logical and effective addition to the technological system currently supporting the DRT operations. The IVT complements the use of existing on-board devices and DRT dispatching technologies and produces a synergistic effect when combined with them thanks to its capability of storing and subsequently displaying multiple dispatch messages (passenger pick-up and drop-off addresses and routing instructions), of recording and provisionally storing specific types of information about each passenger pick-up and drop-off, and of interoperating with the other electronic on board devices, such as automatic odometers, vehicle location devices and card readers. Another important benefit coming from the use of the IVT is that it becomes possible to create more robust and flexible DRT applications, hence giving a more attractive and effective the service. The terminal is also open for future applications and, since it complies with standard in-vehicle networks, interoperable with future on-board devices. This gives the operator the possibility to implement new devices or software in the future without major replacement costs.

When planning or updating an AVM system for regular public transport or for DRT services, the whole life cycle of the system should be taken into account, including possible future changes and applications. Therefore, modularity, openness, updatability and standard compliancy should be included in the selection criteria. The INVETE platform fulfills these criteria and provides a path for making existing in-vehicle infrastructures more simple and modular.

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