



Italian National Agency
for New Technologies,
Energy and Sustainable
Economic Development

Infomobility Systems and Sustainable Transport Services

Edited by

G. Ambrosino, M. Boero, J.D. Nelson, M. Romanazzo

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Sustainable Transport Services

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*“The appropriate deployment of infomobility systems
will significantly enhance the digital economy”*

J.D. Nelson, UK

*“Deployment of Infomobility systems without forgetting the infrastructure,
service, organization and operation dimensions”*

G. Ambrosino, Italy

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Preface

Traffic congestion in European urban and metropolitan areas has already reached unsustainable levels. As recommended by various initiatives and strategies promoted and supported through European Union programmes, most European cities and metropolitan areas are increasingly tackling this problem with an integrated approach, which aims at providing efficient responses to mobility demand and at improving the supply of collective transport services, in addition to encouraging the use of environmentally friendly vehicles and methods.

In parallel, recent years have brought a wide and varied development of technological tools and Information and Communication Technology (ICT) platforms as well as Intelligent Transport Systems (ITS) which cross and permeate different phases of the transport and logistics chain – from traffic planning to traffic management and control throughout the road network, electronic variable message signing, planning and management of operations of public transport fleets, freight transport and goods distribution, etc.

Supported by the use of ITS systems and ICTs, integrated and interoperable platforms are currently being developed, deployed and operated in several cities and metropolitan areas in Europe. Such platforms enable the implementation of effective mobility governance policies based on traffic and transport conditions, increased accessibility to collective transport services as well as greater efficiency and sustainability in passenger and goods transport. These technologies are also relevant from the point of view of both functional and operational integration of the different systems and measures implemented in the transport network, as well as for the provision of updated information to the citizens and mobility demand management.

Flexible transport services (FTS) – such as demand responsive bus schemes, shared taxis, car sharing and car pooling, on-demand city logistics services – are also part of this context, taking advantage of the potential of such technologies and systems to provide services tailored to the actual demand and varied needs of the citizens. This flexibility requires an “elasticity” of planning and operation that can only be obtained through the creation of appropriate solutions and measures for the coordination of the various transport schemes and of the related user information services. Through such measures, European cities, whether by conscious choice or not, are moving towards “infomobility” scenarios, measures and services; i.e. towards operation and service provision schemes whereby the use and distribution of dynamic and selected multi-modal information to the users, both pre-trip and, more importantly, on-trip, play a fundamental role in attaining higher traffic and transport efficiency as well as higher quality levels in travel experience by the users

Addressing the current picture of infomobility scenarios and the landscape of infomobility services deployed across Europe, this volume aims at investigating the different aspects of mobility governance in urban and metropolitan areas, the role played by ICT and ITS infomobility solutions and the organisational and operative problems to be solved. The general issues and concepts underlying infomobility services are illustrated with reference to a relevant number of major European experiences. These are addressed from the different point of view of transport executives and public local authorities as well as from the standpoint of system and service providers. Furthermore, some contributions are devoted to a thorough discussion of institutional and normative aspects and the issue of public-private co-operation, as well as to present the role that public transport can play in the overall infomobility chain.

We believe the approach followed in this book is strongly in line with the different EU initiatives and actions in this relevant policy sector, including e.g. the White Paper on Mobility 2010, the Green Paper “Towards a new culture for urban Mobility” issued in 2007 or the recent ITS Action Plan and CIVITAS initiatives. As such, it will provide a useful reference to investigate this relevant area of mobility management and support the decisions and choices of Local Authorities, Municipalities, Public Transport Companies, Province Councils in the sector, with the background aim, on the one hand, of ensuring efficient implementation of co-modality and, on the other hand, of meeting fundamental city objectives: affecting positively mobility demand, increasing the quality of environment, enhancing the overall accessibility to city mobility services and strengthening social cohesion.

ENEA, the Italian National Agency for New Technologies, Energy and the Sustainable Economic Development, is pleased to contribute to the dissemination of knowledge and promotion of good practice in the field of efficient and sustainable mobility and to publish this book. This work has been realised in collaboration with a large number of

organisations involved in Research and Technological Development in the field of ICT and ITS solutions as well as with organisation engaged in the deployment and operation of advanced systems and services aimed at providing effective day by day responses to the needs of mobility and information services of European citizens while ensuring better quality and liveability of our cities and towns.

Maurizio Romanazzo

ENEA, Italy

CHAPTER 1

Introduction

G. Ambrosino, M. Boero, J.D. Nelson, M. Romanazzo

Since the publication of The European Commission's 2001 White Paper ("European Transport Policy for 2010: time to decide") successive policy statements have highlighted the economic importance of transport by stressing that effective transport systems are essential to Europe's prosperity with respect to economic growth, social development and the environment. The mid-term review of the White Paper "Keep Europe moving" (EC, 2006) stressed the optimization of each transport mode as the way to achieve a clean and efficient transport system; thus prompting a move from the notion of competition between transport modalities to the concept of complementarity. From this perspective it has been recognised that the co-ordination of the different actors is mandatory in order to guarantee the quality and integration of the overall transport chain as a whole. This is more important still for the European cities and metropolitan areas where there is an evident lack of co-ordination among the various public and private entities.

Mobility of goods and persons is an essential component of the competitiveness of European industry and services and it is also an essential citizen right (EC, 2001). Mobility management is also at the heart of the low carbon future debate. At the European level, road transport has significant impacts on climate change with about 12% of the overall EU emissions of CO₂ coming from the fuel consumption of passenger cars (EC-ITS, 2007). It has been argued that improvements in vehicle fuel efficiency have been neutralized by the increased traffic and car size. For example, whilst the EU as a whole reduced its emissions of greenhouse gases by just under 5% over the 1990-1994 period, the CO₂ emissions from road transport have increased by 26% (EC-ITS, 2007).

The relevance of Information and Communication Technology (ICT) applications to support the emergence of Intelligent Transport Systems (ITS) has been recognised with many initiatives during the last 20 years and recently with a specific Recommendation, the “ITS Action Plan” issued by the European Commission (EC, 2008). In the Action Plan ITS applications have been identified as the key element contributing to this efficient co-ordination of the overall transport chain. In a related initiative the EC ITS Roadmap outline sets out the Commission’s policy framework (EC-ITS, 2007) and identifies that there are three major challenges in the provision of sustainable transport. These are: reduction in congestion and optimum use of existing capacity; increase in traffic safety; and addressing the negative impact on the environment with increasing energy efficiency and reducing dependency on fossil fuels. In parallel with the transport technology roadmap, the recent emphasis of the European Commission is on the deployment of ITS for road and their interconnections with other modes of transport (EU, 2008). The EC-ITS roadmap document (2007) also outlined the way forward to achieving a consistent and comprehensive policy framework (organizational, regulatory, funding and standardization), co-operation with the main stakeholders (Member States, industry and user organizations), creating real ownership of different ITS application and stating a business case.

A number of core ITS applications were stated in the EC-ITS roadmap document and feature prominently in the concept of *infomobility* which is developed in this book; these include:

- Seamless real-time travel and traffic information including multi-modal journey planning and information system;
- Freight information systems combining operators’ freight-flow and public authorities traffic flow requirements contributing to the optimum use of road capacity and the reduction of negative impact on the environment;
- eCall leading to a reduction in fatalities;
- Electronic Toll Collection as a key instrument for internalization of external costs;
- Traffic demand management leading to a cleaner road transport and less congestion; and
- The integration of several core applications on an open in-vehicle telematics platform.

This book addresses the context and experience surrounding the recent widespread development of technological tools and ICT platforms to support the emergence of Intelligent Transport Systems. Such developments are notable for the way in which they permeate the transport and logistics chain – from traffic planning to traffic management and control throughout the road network, electronic variable message signing, planning and management of operations of public transport fleets, freight transport and goods

distribution, etc. The development of scenarios, measures and services for infomobility is a prime example of these recent developments.

In this book we offer the following definition of infomobility: the use and distribution of dynamic and selected multi-modal information to users, both pre-trip and, more importantly, on-trip, in pursuit of attaining higher traffic and transport efficiency as well as higher quality levels in travel experience by the users. As such, “infomobility” manifests itself through a variety of scenarios, measures and services; key examples of which are described in the chapters which follow.

Structure of the chapters

CHAPTER 2 discusses four distinctive aspects of a technological platform for infomobility. The first aspect is the policy framework. Section 2.2 introduces the concept of co-modality arguing that this is mandatory in order to guarantee the overall quality of the passenger and logistics systems as a whole. Following guidelines produced by the European Commission the use of ICT tools and systems has been identified as the key element contributing to the efficient and sustainable co-ordination of the overall transport and logistics chain. ITS Reference Architectures to support European and national initiatives are discussed in detail in Section 2.3 and the technical specifications for multi-modal travel and traffic information services (TTIS) and technologies are explored in Section 2.4. TTIS address fundamental needs of the individual travellers by providing better information about available travel options, while also providing effective means for traffic and transport authorities to pursue global objectives such as improved safety, overall transport efficiency and decreased environmental impacts. At a finer grain a detailed analysis of decision support for trip planning is given (Section 2.5) to illustrate the objective of determining the optimal itinerary from an origin to a destination according to the traveller’s preferences, utilising the relevant available transportation services.

Most European cities and metropolitan areas are increasingly tackling the problem of unsustainable levels of traffic congestion by adopting an integrated approach, which aims at providing efficient responses to mobility demand and at improving the supply of collective transport services, in addition to encouraging the use of environmentally friendly vehicles and methods. The objective of CHAPTER 3 is to showcase infomobility in practice by highlighting innovation and good practice across a variety of urban and metropolitan locations in Europe. The appropriate use of information, the vital commodity, of the 21st century Intelligent Transport System, is illustrated by applications of strategic traffic and mobility management systems (Aalborg, Rome, Florence, Berlin, Cagliari); real-time information for travellers (Cambridge); optimum public transport information (Naples, Vienna), Bus Rapid Transit (Quito); and the flexible transport Agency (Europe).

CHAPTER 4 is complementary in scope to the previous chapter; here the scale of analysis is the regional and extra-urban level and experiences and applications of infomobility in practice are presented from across Europe. This chapter considers four quite distinct cases beginning with intermodal real-time door-to-door travel information in the Vienna region drawing on experience in the In-Time project. The second example is “Ruhrpilot”: a regional traffic information and management system for one of Europe’s most congested regions. In this case a variety of commercial, administrative and technological factors across jurisdictional borders have been overcome. The scope in Section 4.4 is overtly rural with a case study from Highland Region, Scotland which describes an application of infomobility for the labour force through development of the Transport to Employment (T2E) service which has implemented the Agency approach to flexible transport based on the use of shared taxis. Finally, a technical analysis of traffic monitoring and control systems on motorways including an analysis of safety in tunnels is presented drawing on experience in Italy.

In CHAPTER 5 the focus is on the crucial issues of decision support, safety and incident management. Whilst Authorities are developing initiatives to manage traffic, improve safety and provide a range of services to support mobility, no remedial strategy can be better than the information upon which they have to rely. Section 5.2 addresses this proposition through an overview of the state-of-the-art and the challenges of car-to-car and car-to-infrastructure communications technology, both of which show a strong potential to enhance the capabilities in the field of traffic management operations, infomobility services and safety of road users. The prediction of incident duration on motorways is discussed in Section 5.3 by a review of previous studies on incident duration prediction, exploratory analysis of incident data and the construction and testing of five incident duration prediction models. Finally, a decision support system for traffic incident management in roadway tunnel infrastructure is presented in Section 5.4.

Evaluation issues are addressed in CHAPTER 6 which introduces two case studies of good practice in evaluation each illustrated by an example of an infomobility application which has been discussed in earlier chapters. The first (Section 6.2) introduces a methodology, known as DESTINO, for identifying the main factors which need to be considered in the decision process when designing and delivering a flexible transport service. Such preliminary work at the design stage of a transport system is extremely important as it forms an integral part in the development of an evaluation framework. The DESTINO methodology is designed to be transferable and is thus available for the planning and evaluation of a variety of infomobility applications. The second case study (Section 6.3) is a detailed method for the analysis of performance reliability of transport services which draws on work conducted as part of a COST research action on Buses with a High Level of Service (Action TU 603). In addition to a state-of-the-art review

of the indicators and methods currently used for evaluating public transport services performance a proposal for evaluating reliability of a service is illustrated by a synthesis of experience on some European BHLS lines.

It is essential that the objectives and results that are planned from the introduction of an ITS system are achieved in a consistent way. This means that appropriate resources and time must be spent in the management of the overall planning and purchasing lifecycle. CHAPTER 7, the final chapter of this book, attempts to provide specific elements supporting Public Authorities in this process. SECTION 7.2, provides the most important guidelines for carrying out the feasibility analysis in terms of the reference context (legacy systems, other ITS systems that are running, etc.), organisational model and operational procedures currently used, regulation and institutional issues, users needs.

Detailed guidelines and recommendations for the management of the tendering process are provided in SECTION 7.3. The most important issues are described according to the proposed scheme of the documentation: administrative obligations and procurement rules, technical specifications, description of the modalities to present the technical proposal. In particular, with regards to administrative and contractual obligations, this section introduces and describes the obligations required to carry out the monitoring and the acceptance of the system under the complete control of Contracting Administrations (guarantees, arrangement of payments, testing procedures, penalties, application rules for performances indicators, etc.).

Finally, SECTION 7.4 discusses how the evaluation process is performed through the following steps: definition of award criteria in a consistent way with the technical specifications; detailed specification of award criteria into sub-criteria; definition of relevant weights for award criteria and sub-criteria; and application of a methodology based on the defined criteria and sub-criteria and the required modalities for the description of the technical proposal.

Infomobility systems: reference architectures and enabling technologies

2.1 Introduction

The previous chapter has referred to the circumstances underlying the recent widespread development of technological tools and Information and Communication Technology (ICT) platforms to support the emergence of Intelligent Transport Systems (ITS). Such developments are notable for the way in which they permeate the transport and logistics chain – from traffic planning to traffic management and control throughout the road network, electronic variable message signing, planning and management of operations of public transport fleets, freight transport and goods distribution, etc. The development of scenarios, measures and services for infomobility is a prime example of these recent developments.

This chapter discusses four distinctive aspects of a technological platform for infomobility. The first aspect is the policy framework. Section 2.2 introduces the concept of co-modality arguing that this is mandatory in order to guarantee the overall quality of the passenger and logistics systems as a whole. Following guidelines produced by the European Commission the use of ICT tools and systems has been identified as the key element contributing to the efficient and sustainable co-ordination of the overall transport and logistics chain.

ITS Reference Architectures to support European and national initiatives are discussed in detail in Section 2.3 and the technical specifications for multi-modal travel and traffic information services (TTIS) and technologies are explored in Section 2.4. TTIS address fundamental needs of the individual travellers by providing better information about available travel options, while also providing effective means for traffic and transport authorities to pursue global objectives such as improved safety, overall transport efficiency and decreased environmental impacts. At a finer grain a detailed analysis of decision

support for trip planning is given (Section 2.5) to illustrate the objective of determining the optimal itinerary from an origin to a destination according to the traveller's preferences, utilising the relevant available transportation services.

2.2 Co-modality and Integrated Info-Mobility Management in European Cities

S. Gini, G. Ambrosino, J.D. Nelson

2.2.1 Co-modality in the urban/metropolitan mobility context

The concept of co-modality has been promoted by European Commission from the Lisbon Agenda as the most profitable way to guarantee the sustainable growth of competitiveness in Europe. The White Paper "European Transport Policy for 2010: time to decide" (EC, 2001) states the need to develop competitive logistics solutions based on integrated transport modalities and the mid-term review of the White Paper "Keep Europe moving" (EC, 2006) indicated the optimization of each mode as the way to meet the objectives of a clean and efficient transport system. The same Paper fostered the replacement of the notion of competition between modes with the concept of *complementarity*.

From this perspective co-ordination of actors is mandatory in order to guarantee the overall quality of the logistics systems as a whole. As stated by the guidelines produced by the Commission the use of ICT tools and systems has been identified as the key element contributing to the efficient and sustainable co-ordination of the overall transport and logistics chain.

On the other hand, as discussed below, the wider and wider use of ICT tools is one of the weak points hampering the real achievement of a full-integrated interoperability platform in the co-modality chain.

Barriers to achieving full co-modality

Despite the efforts already put in practice much work remains to be done as the vision of a full co-modality is still far from reality. Indeed many well-defined technical, cultural and operational barriers (Mulley and Nelson, 1999) continue to hamper the achievement of the defined goals. Far from accomplishing a full co-modality among different transport modes, interoperability is often lacking at a single transport mode. For example in the sea transport mode, obstacles that impede the further development of shipping can be overcome with (full) integration into door-to-door multi-modality, in the complexity of the documentation and administrative procedures and in cultural heritage (it is still seen as an old-fashioned mode of transport).

Generally, the deregulation and the liberalisation of the transport market that took place across Europe from the 1990s has brought about a fragmentation of multiple small

firms (this effect is even clearer in the road transport mode where it is epitomised by the “one man, one truck” company). This fragmentation is already a consistent obstacle to be overcome to guarantee an efficient co-ordination of the co-modality chain.

From the technological point of view the above mentioned fragmentation is accompanied by a wide range of ICT solutions in terms of concepts, requirements and information management. Even if ICT tools and solutions are in rapid evolution and expansion the state-of-the-art is still clearly divided in two main different conditions: while the larger industries commissioned and implemented proprietary systems since the beginning of E-Logistics, ICT solutions initially found it hard to take a role among SMEs; but now they are largely introduced (due to the decreasing costs) often in an irrational way. The better co-ordination of actors must be supported by a required standardization of procedures and by the development of integrated IT concepts and solutions that nowadays is lacking.

Trends in the urban/metropolitan areas: requirements for the co-modality transport offer

The concept of co-modality is becoming more and more relevant for transport of people and goods in the European cities due to the changes to the overall city logistics/life style (in a wider sense that includes goods distribution, productive processes and passengers' flows). Indeed with regards to passenger transport changes in the lifestyle and behaviour have brought about relevant changes in the mobility demand: these changes consist of the increase of systematic compared to erratic journeys. With regards to goods distribution the on-going changes are affecting not only the way goods are sold but also how they are delivered and how the related information must be managed and made available. In order to respond to these changes the role of co-modality (as integrated transport modes) is becoming the key element that fosters the setting of higher requirements and expectation by the final consumers/clients in terms of transport service accessibility, flexibility, affordability, quickness, cost reduction and the availability of real-time information. In this scenario the role of ICT systems and web platforms/solutions/services (B2B, B2C) is becoming fundamental in order to support a wide range of activities in the management and operation of the transport and logistics chain (communication technology and fixed networks, mobile platforms, user information at bus stops, on-board display and held-hand devices, vehicle positioning systems, tracking and tracing technologies, models and software tools for service planning and programming, etc. – see Ambrosino et al, 2005).

2.2.2 Co-modality and Integrated Urban Mobility Management

Generally speaking, it is necessary to identify the reference scenario in which such solutions/services should be produced, operated and exploited in order to address the co-modality issue. On the whole the following main issues should be considered:

- *Territorial features*: dimension, presence of an historical centre, features of the network, etc.
- *Transport mode*: public/private, freight/passenger, co-modality/intermodality, road/tram, etc.
- *Clients*: citizens (or groups of citizens), economic categories/associations (i.e. shopkeepers associations); logistics/mobility/transport operators; Authorities and stakeholders with different levels of responsibility/actions
- *Existing infrastructures*: including both physical infrastructures (gates, terminals, CDU, road topology, fleets typology, Tram/BRT infrastructures, etc.) and ITS solutions and systems (traffic light control, variable message signs, goods distribution platform, etc.) at network/service level.

These aspects are not exhaustive and are tightly inter-related taking into account the overall city logistics chain and the supplier/producers of information. Furthermore, it is necessary to define the bounds of co-modality (and in particular of goods distribution services) in relation to the other relevant issues which affect the implementation and operation of Mobility and Transport services, including the problem of service *accessibility*; this should be both at physical and e-services level (as faced by the FP7 KOMODA project's solutions in E-logistics) including all the ICT devices and ITS systems involved. All of the above mentioned issues are certainly more relevant in the urban and metropolitan areas, particularly taking into account the situation of European cities and towns.

In current scenarios of urban mobility, many constraints (ranging from the urban structures and environmental issues to regulations, costs of road infrastructure and community budget limits) lead Local Authorities to look for ICT tools and systems as a fast and efficient response to a number of complex and compelling issues including traffic congestion and pollution, poor accessibility and low usage of public transport and lack of sustainable mobility schemes for increasing service efficiency (including the logistics services). There is often an evident lack of co-ordination among the various public and private entities – car traffic, public transport services, freight and goods transport operators, emergency services, etc. – sharing the same road infrastructure with different aims, roles and responsibilities. This generates negative impacts whose cumulative effect is very visible in terms of environmental quality and sustainability of city life.

Therefore challenging co-modality in urban and metropolitan areas means the realisation of an Integrated Mobility Management and Control System based on an ICT Reference Model. The model is generally composed by a two-level hierarchical architecture consisting of a bottom level (single system level) and an upper one (co-ordination level). The bottom level manages the specific processes operating on the network using their own control and implementation strategies (and related devices). Furthermore this level operates as a data provider for the upper level that implements the analysis of network conditions and the implementation of mobility strategies and / or actions. Detailed

description of this model relating to the Florence metropolitan context is provided in Section 3.4.

In the Reference Model it is possible to identify several key “**axes**” which could guarantee effective co-modality in the urban and metropolitan areas (illustrated for the case of the Florence metropolitan area in Section 3.4). Together with these key “axes” other **added value services** can be defined and provided. Examples of these services can be: city logistics, traffic and travel information, access control for limited traffic zone, pricing schemes, tourists’ bus service.

The definition and the implementation of the above architecture should be fostered by a Master Plan for ITS Services defining the best options for the implementation of technologies and services in the area on the basis of the objectives set by the City Authorities. In recent years examples of such Master Plans have been defined by European cities and large metropolitan areas: for detail please see the Florence case.

However, from the operational point of view, an analysis of the main and urgent needs of mobility governance in the metropolitan area should be conducted in order to design an effective ITS operational framework able to allow the implementation of co-modality solutions and services on the basis of the objectives provided by the policy makers. Taking into account this scenario, one of the first steps required for strengthening the co-modality approach in a short time relate to actions on public transport fleet operation and parking management systems as implementation of Bus Rapid Transit (BRT) corridors and flexible feeder services to the conventional public transport network / lines, traffic light priority and co-ordination, users information, routing through variable messages panels, integrated payment system. These can bring about advantages and effective benefits on:

- commuters mobility with the capability to provide information and support facilities for modal shift at relevant network points/terminals;
- the provision of added value services to some mobility demand segment not covered by the conventional services (lines with predefined timetable and fixed lines);
- more efficient use of the available transport resources;
- contribution to the improvement of environmental conditions.

This approach is confirmed by different EU actions and initiatives (from the White Paper on Mobility 2010 to the Green Paper “Towards a new culture for urban Mobility” issued in 2007 or the recent ITS Action Plan and the CIVITAS Initiatives) which have begun to strongly influence the decisions and choices of Local Authorities (Municipalities, Public Transport Companies, Province Councils, etc.). These strategies aim to achieve relevant city objectives (affecting mobility demand, increasing quality of environment and overall accessibility to city services, strengthening social cohesion) through a real and efficient implementation of co-modality solutions.

2.3 ITS Reference Architectures to support European and national initiatives

M. Boero, A. Lumiako

2.3.1 Introduction

The concept of ‘System Architecture’ (SA) is a general notion underlying the theory and practice of complex systems in most engineering fields. A quite general, collaboratively defined and updated definition of a System Architecture can be found in Wikipedia: “*A system architecture is the conceptual design that defines the structure and/or behaviour of a system. An architecture description is a formal description of a system, organised in a way that supports reasoning about the structural properties of the system. It defines the system components or building blocks and provides a plan from which products can be procured, and systems developed, that will work together to implement the overall system*”. The main goal of a (formal) definition of a System Architecture is then providing a common, unambiguous description of the concerned system allowing different people to “work on” the specification for different purposes, from engineering activities (e.g. design, extension, implementation, maintenance, etc.) to business and commercial oriented issues (e.g. tendering, procurement, evaluation, product/product line creation, etc.).

Over the last decade, much considerable effort has been put into defining “Reference System Architectures” in a number of engineering fields including, for instance, telecommunications, manufacturing and production systems, enterprise systems. With the dramatic growth of the Internet, recent important initiatives include, particularly, the definition of reference models for Service Oriented Architectures in future scenarios of pervasive on-line services¹ and future visions and evolutions of the Internet itself².

The goal of a Reference System Architecture is to provide a common reference for the definition and development of a System Architecture in a context where multiple parties (i.e. multiple designers, system/technology suppliers, vendors, service providers, operators, etc.) are interested in and engaged into the definition, implementation, deployment and operation of the target system. In this respect, the *interoperability* of the different parts of the systems – i.e. the various sub-systems, components, services, technologies, etc. – is a key issue and goal the Reference SA is expected to address and help achieving by facilitating a consistent development of system design and the adoption of the relevant technology standards.

The ITS engineering field is no exception to this general approach. With strong support by the European Commission, the development of ITS Reference System Architectures dates back to the first ITS European programmes like DRIVE and Transport Telematics,

1 see e.g. NEXOF-RA, the Reference Architecture for the NESSI Open Service Framework (NEXOF) developed under the NESSI European Technology Platform (<http://www.nessi-europe.com/>).

2 see e.g. the Future Internet Reference Architecture work developed within the Future Internet Assembly (<http://www.future-internet.eu/>).

which undertook preliminary work to stimulate a common European vision in the field. Activities are still ongoing today, with recent targeted projects part-funded by the EC such as FRAME and e-FRAME³. Similar initiatives are ongoing also outside Europe – notably, in North America (USA⁴, Canada⁵), Japan, Australia⁶, Arab Countries⁷ – and at the level of individual EU member states, with programmes launched in such countries as Austria (TTS-A), Czech Republic (TEAM), Finland, France (ACTIF)⁸, Italy (ARTIST)⁹, The Netherlands and United Kingdom among others.

2.3.2 The European ITS Reference Architecture

Partly supported by EU financing and policy development, the ITS world in Europe has put great efforts into developing a European ITS Reference Architecture as a main instrument to stimulate the growth of a competitive market of ITS applications, products and services. The European ITS Framework Architecture – named FRAME – has evolved through a number of targeted EU initiatives and provides the overall guidelines and a high-level approach to support the planning, development and implementation of ITS in Europe. Initially developed in the framework of EU projects such as CONVERGE and KAREN, the reference architecture has a main focus on road transport ITS applications and encompasses eight main areas: Traveller Journey Assistance, Traffic Management, Public Transport Operations, Freight and Fleet Operations, Advanced Driver Assistance Systems, Safety and Emergency Facilities, Support for Law Enforcement and Electronic Payment. The specification work initiated by CONVERGE and KAREN was then continued in the follow-up FRAME projects (Framework Architecture made for Europe) and the linked projects FRAME-NET and FRAME-S, promoting the use of the Framework Architecture in a number of research and industrial projects and providing support to the users in using the FRAME guidelines. Taking over FRAME and the FRAME Forum, e-FRAME is the currently ongoing (2008-2011) initiative providing further development and consolidation of the European FRAME architecture, particularly as regards the extensions needed to address ITS Cooperative Systems.

Elements and organisation of FRAME Architecture

Overall, the FRAME architecture is a very large specification comprised of

- i) a set of User Needs capturing the main requirements and needs of the different categories of users of ITS applications and services;

3 European ITS Reference Architecture <http://www.frame-online.net>

4 USA National ITS Architecture <http://www.iteris.com/itsarch/>

5 ITS Canada Reference Architecture <http://www.its-sti.gc.ca/en/architecture.htm>

6 ITS Australia <http://www.its-australia.com.au/>

7 ITS Arab Countries <http://www.itsarab.org/>

8 French ITS Architecture ACTIF, <http://www.its-actif.org/>

9 ARTIST, the Italian National ITS Architecture, <http://www.its-artist.rupa.it/>

- ii) a Functional Viewpoint providing the definition of functionalities/services and their connections necessary to support the identified User Needs (Functional Architecture);
- iii) a Physical Viewpoint, describing how the various elements (i.e. systems and sub-systems) of the Functional Architecture can be mapped onto concrete elements having physical identity and implementing the specified functionalities and services;
- iv) a Communication Viewpoint, addressing the elements ensuring communication and information exchange among the elements of the Physical Architecture;

The Functional Viewpoint is of a particular importance, providing a description of the system in functional terms and clarifying the kind of services offered to the users. It also shows how system functionalities link to the outside world; i.e. the various kind of users of the system and the data that is used within the system.

According to the original goals of FRAME/e-FRAME (see, particularly, <http://www.frame-online.net>) the objective of the European ITS Architecture is to provide a reference framework to ensure that whichever level – i.e. national, regional, or city– and transport specific sector or service is addressed, the implementation and deployment of the resulting ITS architecture meets a number of strategic needs:

- can be planned in a logical manner;
- integrates successfully with other systems;
- meets the desired performance levels;
- features the desired behaviour;
- it is easy to manage, maintain and extend;
- satisfies the expectations of the users.

Particularly, the capability of integrating with other systems is a key requirement of any ITS application which is strongly supported by the Reference Architecture and the associated methodology. In this respect, developing any ITS architecture in compliance with the Reference ITS Architecture will mean, essentially, the capability for the systems/applications to work together and to be made interoperable at the European level. This is a key motivation behind the concept and development of the FRAME Reference Architecture, which is seen as a major enabler for the take up of an European open and competitive ITS market.

Functional Areas within the FRAME Architecture

Overall, the FRAME architectures addresses eight main functional areas within the road ITS domain: (1) Provide Electronic Payment Facilities, (2) Provide Safety and Emergency Facilities, (3) Manage Traffic, (4) Manage Public Transport Operations, (5) Provide Advanced Driver Assistance Systems, (6) Provide Traveller Journey Assistance, (7) Provide

Support for Law Enforcement, (8) Manage Freight and Fleet Operations. Table 2.1 at page 35 provides a summarised definition of each main functional area.

Each functional area includes a number of functions defined at different levels of abstraction (high-level functions and low-level functions). The relationships among each function and sub-function are expressed by Data Flows showing the data which are sent from one function to another, to or from the function to Data Stores (i.e. sources/repositories of information) or Terminators (i.e. elements of the external world, like users or external systems). These relationships are graphically expressed by Data Flow Diagrams (DFDs). Generally, there is a DFD for each Functional Area and one for each of the High Level Functions contained in each area. Figure 2.1 below provides an example of DFD taken by the FRAME architecture, Functional Area “Provide Electronic Payment Systems” (the figure 2.1 shows only part of the entire DFD).

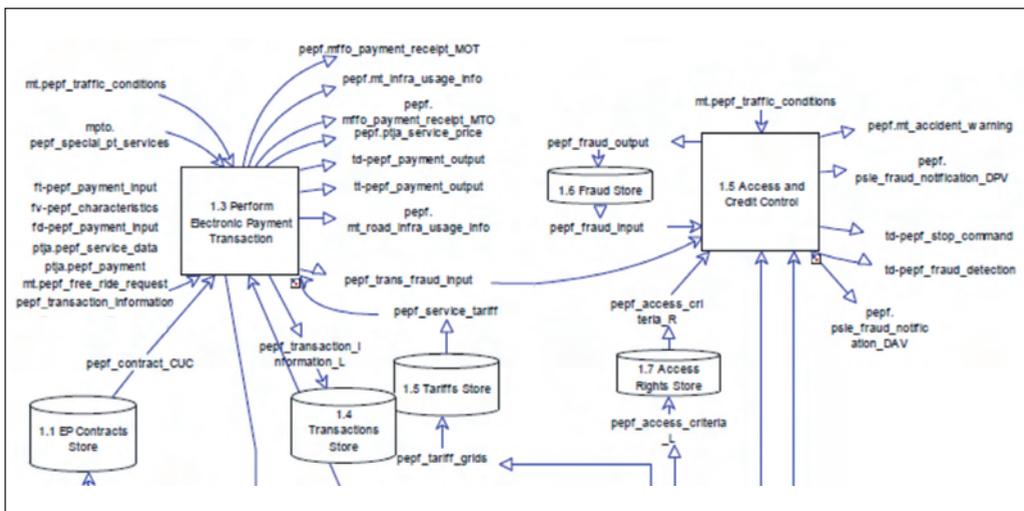


Figure 2.1: Example of Data Flow Diagram: part of FRAME Functional Area “Provide Electronic Payment Facilities” (source: KAREN / e-FRAME project, <http://www.frame-online.net>)

Functionalities related to the Travel and Traffic Information Services

The functionalities and aspects related to the domain of Travel, Traffic and Mobility Information are addressed in several parts of the FRAME architecture specification.

Area 2 “Provide Safety and Emergency Facilities” and Area 3 “Manage Traffic” contain elements related to information generation and provision. Core low-level functions and their relevant data /information include, for instance: predictions of traffic conditions for the urban and inter-urban road networks, provision of car park and service areas occupancy levels (states), provision of tunnels and bridges status information, weather information, incident information, etc.

Area 4 “Manage Public Transport Operations” includes a number of functions addressing user information generation and provision related to public transport services. Static information (related to service planning) is covered, including, for instance, timetable, route and fares information. Dynamic information is addressed as well, including estimated times of arrival of vehicles at stops, delays, service variations.

Area 5 “Provide Advanced Driver Assistance Systems” addresses in-vehicle applications and services. This includes information such as floating car data that can be used for implementation of traveller information services. This area is expanded as result of recent developments in the area of Cooperative Systems, conducted mainly in the framework of the COMeSafety, COOPERS, CVIS and SAFESPOT projects.

Area 6 “Provide Traveller Journey Assistance” addresses both pre-trip and on-trip phases and provides functionalities enabling travellers to plan and complete trips using the relevant travel information. Once a trip is in progress, the traveller’s plan (i.e. itinerary, time) can be adapted in case of any change or significant event occurring in the part of the transport network of interest for the traveller. This might be the case, for instance, of incidents or service perturbations in the case of multimodal travels. This is also covered in the provision, if necessary, of driving instructions to the traveller (dynamic route guidance).

Figure 2.2 at page 37 provides the complete DFD of the functional area “Provide Traveller Journey Assistance” showing the high-level functions the area is composed of and the relevant data flows. Overall, four main high-level functions are defined:

F 6.1 Define Traveller’s General Trips Preferences (GTP)

F 6.3 Support Trip

F 6.4 Evaluate Trip

F 6.5 Prepare Trip Plan

According to the KAREN original formulation, the four Functions in this Area support the entire chain enabling the traveller to plan a trip on the basis of General Trip Preferences (GTP’s) and/or Actual Trip Preferences (ATP’s). The planning/execution activity is interactive, allowing to the ATP for the trip be adapted whenever the initial preferences no longer meet anymore users expectations. Users can also continuously refine trip choices until the actual itinerary is satisfactory.

Area 6 functionalities support intermodal trip planning and execution. Users trips can cover several modes, including, in addition to cars and buses, the other modes outside the road domain (i.e. rail, air and maritime). In addition, other information and services are includes such as: (a) Points of Interest and information about other facilities that will be encountered when the trip plan is implemented, (b) bookings for any of the services involved in the planned and accepted trip plan, (c) payments for any of such services.

The resulting trip provides the planned journey structure that will be implemented and, eventually, adapted and improved based on actual information and user’s choices

Identity	Name	Description
Area 1	Provide Electronic Payment Facilities	This Area shall provide functionality that enables the acceptance of payment for services provided by other Functional Areas within the Architecture. It shall have an interface with the Financial Clearinghouse terminator to enable actual payment transactions to be made. If payment violations are detected, any details that are available shall be passed to functionality in the Law Enforcement Area.
Area 2	Provide Safety and Emergency Facilities	This Area shall provide functionality that enables the Emergency Services to respond to incidents. The Functions in this Area shall have links with the Manage Traffic Area to enable the reporting and detection of incidents, the management of their impacts and the granting of priority to Emergency Vehicles. It shall be possible for priority to be provided either locally at each controlled point on the road network, or as a "route" through the network. There shall be links to the Provide Traveller Journey Assistance Area to enable priority routes for Emergency Vehicles to be produced.
Area 3	Manage Traffic	This Area shall provide functionality enabling the management of traffic in urban and inter-urban environments. Functionality shall be included to detect and manage the impact of incidents, produce and implement demand management strategies, monitor car park occupancies and provide road transport planning. Links shall be provided to the Provide Safety and Emergency Facilities and Manage Public Transport Areas so that their vehicles are given priority through the road network and to enable assistance to be provided in the implementation of incident and demand management strategies. The External Service Provider terminator shall be sent data about traffic conditions and strategies.
Area 4	Manage Public Transport Operations	This Area shall provide functionality to enable the management of Public Transport. It shall include the scheduling of services and the generation of information that can be made available to travellers. The Area shall have links with the Manage Traffic Area to provide priority for its vehicles, and to provide data on the use of services so that an assessment can be made of demand for different modes of transport. The Manage Traffic Area shall also provide requests for service changes to enable a move towards a better balance in the use of transport modes. There shall also be links to other Areas to provide information about fraud and incidents that have been detected in the Public Transport network.
Area 5	Provide Advanced Driver Assistance Systems	This Area shall provide functionality that enables the control of vehicles whilst they are using the road network. Interfaces shall be provided to the Provide Safety and Emergency Facilities Area to provide a speedy response to "mayday" calls from vehicles. Vehicle identities shall be provided to other Areas for payment collection and the identification of fraud. Functionality shall also be provided to enable the output of traffic and travel information provided by the Manage Traffic Area.
Area 6	Provide Traveller Journey Assistance	This Area provides functionality that enables the provision of information to all types of Travellers about traffic conditions and about other modes of transport. Functions also provide route determination and guidance, plus travel planning. This includes access to other services such as accommodation.
Area 7	Provide Support for Law Enforcement	This Area shall provide functionality to enable the provision of an interface to Law Enforcement agencies. This interface shall be used to provide information about frauds and violations that have been detected by functionality within other Areas. Examples of frauds and violations shall include but not be limited to invalid or missing payment, speeding, incorrect use of lanes in the road, incorrect observance of other commands sent to drivers. Over-weight vehicles shall be detected by functionality within the Area itself and the details passed to the Law Enforcement Agency.
Area 8	Manage Freight and Fleet Operations	This Area shall provide functionality that enables the management of Freight and Fleet Operations. This shall control the use of freight vehicles and their transportation of goods. The use of other modes of freight transport shall also be supported. An interface to the Provide Safety and Emergency Facilities Area shall also be included to enable the provision of information about hazardous goods. Route planning for this and other types of goods shall be provided through the interface to the Provide Traveller Journey Assistance Area.

Table 2.1: Main Functional Areas of FRAME architecture

(e.g. in reaction to changes and events in the concerned transport network) as the trip progresses.

The general definition of this Functional Area also includes supporting functions and facilities such as:

- the capability of updating trip data in the GTP once the trip is completed;
- the possibility for the Travel Information Operator to generate a trip evaluation report, showing the degree of success of the trip and any changes with respect to the planned trip;
- the capability for the user (traveller) of using the service to obtain only trip information rather than for actually planning a trip;
- the capability of charging users for the trip planning/information service itself, if required for a particular ITS deployment.

2.3.3 Conclusions

The European ITS Architecture FRAME briefly outline in this section – with a main emphasis on those parts more related to the theme of this volume: Travel and Traffic Information Services – provides a general reference framework for the design, development and implementation of ITS architectures and services able to meet high-level, strategic objectives for the ITS domain: providing open systems, able to interoperate each other to the maximum possible extent, supporting standardisation and stimulating a competitive, open European market of applications and services.

The Reference Architecture should be seen as a descriptive and also practical tool to analyse and understand the properties of existing Travel and Traffic Information services and systems, as well as to design new ones within a coherent and consistent framework. In this respect, the FRAME specifications and the accompanying methodology are complemented by practical, usable IT tools – the Architecture Browsing and Selection tools, freely downloadable from the eFRAME website¹⁰ - created to facilitate the consultation and use of the specifications. These enable the user to browse the defined User Requirements and the associated Functional Viewpoint, select the areas of interest and generate a consistent functional and physical architecture meeting the own user goals and requirements in the framework of the general FRAME Reference Architecture.

The European ITS Reference Architecture specifications are currently in a phase of further consolidation and evolution, particularly in relation to the most recent efforts and developments in the growing area of Cooperative Mobility Systems.

36 ¹⁰ <http://www.frame-online.net>, section 'Architecture'.

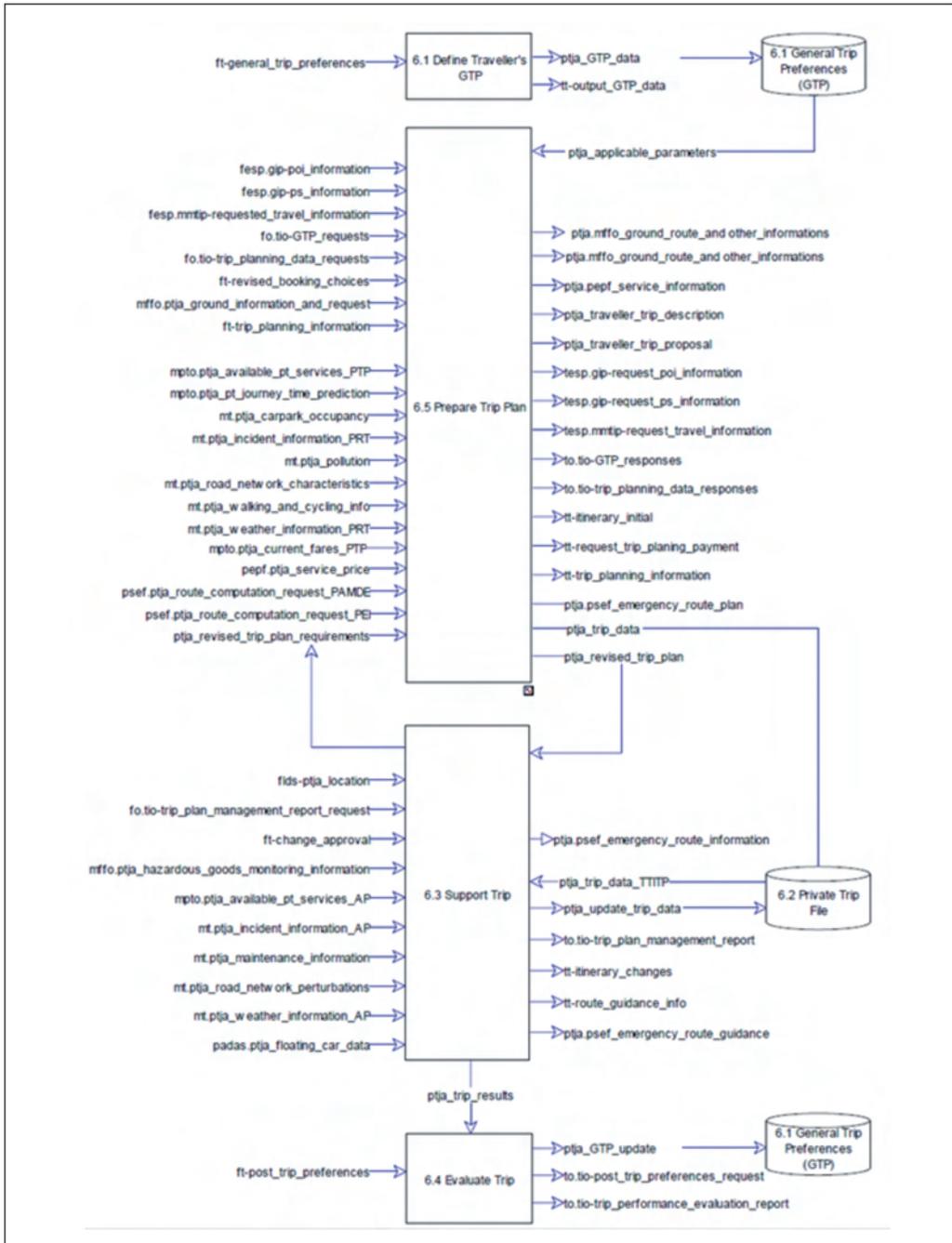


Figure 2.2: Data Flow Diagram of FRAME Functional Area “Provide Traveller Journey Assistance” (DFD 6) (source: KAREN / e-FRAME project, <http://www.frame-online.net>)

2.4. Multi-modal travel and traffic information services and technologies

M. Boero, H. Kirschfink, M. Masnata, J. Scholliers

2.4.1 Introduction

Multi-modal Travel and Traffic Information Services (TTIS) provide essential information to travellers with the aim of enabling efficient travel planning and better adaptation of the travel to the changing conditions of the transport environment. The background goal of such systems is twofold, to achieve both individual and collective transport benefits. On the one hand, TTIS address fundamental needs of the individual travellers by providing better information about available travel options, enabling better planning and decisions and ensuring improved travel efficiency and comfort. On the other hand, they provide effective means for traffic and transport authorities to pursue global objectives such as improved safety, overall transport efficiency and decreased environmental impacts.

Addressing different transport and traffic modes – from car traffic, in both urban and interurban environments, to passenger mobility services, freight transport and logistics – TTIS usually provide information and advice in two main phases of the travel:

- **pre-trip**, i.e. before the actual start of the travel, involving information known in advance, essentially of a static or semi-static nature or, and helping in travel planning and decision taking;
- **on-trip**, i.e. during the execution proper of the travel, involving real-time information which changes frequently as an effect of traffic and transport dynamics and unpredicted events.

Generally, information and services can be delivered to the users via a number of different devices and technologies, depending also on the particular travel phase addressed and on the kind of information involved. This ranges from pre-trip information and services delivered through the Internet and TTIS web portals accessible via desk computers, to on-trip information distributed to the travellers on the move via in-car navigation devices, portable terminals (e.g. palm computers, 3G phones, etc.), radio, roadside variable message signs (VMS), etc.

Figure 2.3 provides a generic representation of the service chain underlying the operation and provision of travel and traffic information. This usually implies both **public** and **private providers**, involved with different roles and responsibilities in the service production process. TTIS provision was historically originated mostly by public providers operating traffic and transport management technical infrastructures and systems. The strong and steady increase of mobile phone and vehicle tracking technologies in the last few years has given private service providers an increasingly important role.

38 More market-oriented scenarios and service provision schemes have finally emerged, as

sometimes private service providers can have better information about the traffic situation than the road operator.

On the other hand, as traffic safety is a major concern and goal for any Intelligent Transport System, the role of public operators and service providers remains a crucial one in the market of TTIS, since updated and timely information is to be made available to all players on a fair and equal basis.

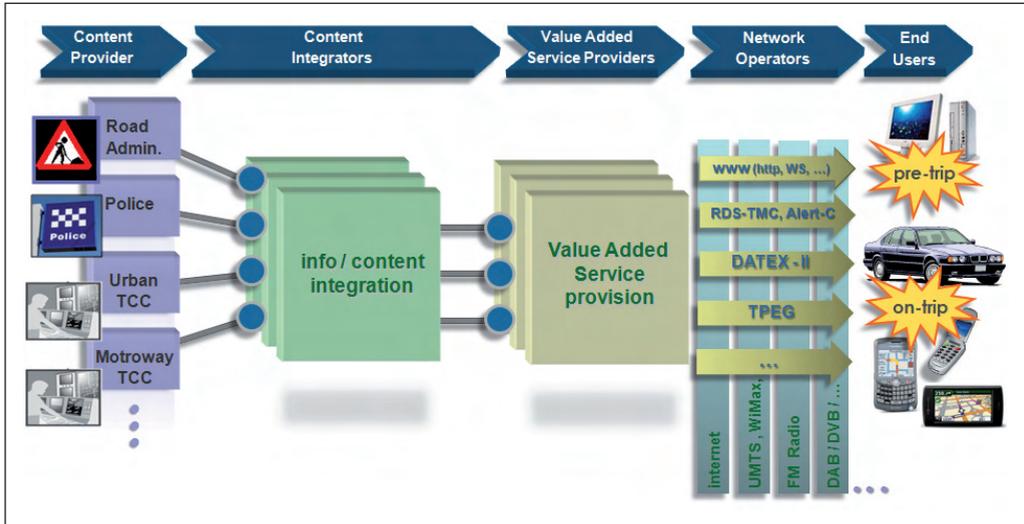


Figure 2.3: Travel and Traffic Information Service chain

The remainder of this chapter provides an overview of the current field of Travel and Traffic Information Services in Europe, illustrating the general kinds of TTIS currently considered in this area, the main issues behind TTIS implementation and provision, the actors involved in the service and value chain as well as the main enabling technologies and systems used for service operation and delivery to the target users.

2.4.2 Definition of Travel and Traffic Information Services

The implementation of modern and effective Travel and Traffic Information Services for the European citizens has been a major goal of the EU for almost 20 years. A number of initiatives have been undertaken in this area, involving both public authorities, service providers and the industry, and this has led to a number of systems and services deployed and operated in most EU countries. Such initiatives have also contributed to the development of common views and solutions that have greatly improved the understanding of TTIS and have stimulated the adoption of cross-country solutions addressing the so-called Trans-European Road Network (TERN) and the growth of the internal European market in this important area of ITS.

An overview of current TTIS applications in Europe can be better understood in the context of the recent European TEMPO programme (2001-2006), which has supported and guided the realization of several Euro-Regional ITS implementations including TTIS systems and services.

The TEMPO classification for European ITS

The document “Final Report on the review of European ITS services” (D1.4) (TEMPO, 2003), provides a distinction between “**Minimum ITS Services**” and “**Common ITS Services**”. Minimum ITS Services “are considered as being essential and should become available in all EU Member States”; common ITS Services “should be compatible wherever available”. Minimum ITS Services include the following:

- **Multi-modal trip planning:**

These trip planning services aim to encourage travellers to make the best choice in terms of mode of travel.

- **Real-time traveller information:**

Real-time services are used to optimise the journey for the traveller by reducing or avoiding delays on the network. Four services have been identified:

- Pre-trip road traffic information
- Pre-trip public transport information
- On-trip real-time road information
- Real-time (on-trip) passenger information

- **Emergency handling:**

This service improves the response to problems on the network and thus the safety of travellers improves and the likelihood of recovery of those injured in accidents rises. It also reduces delays to other network users.

- **Electronic Fee Collection:**

This service enables non-stop payment of road charges throughout Europe (electronic fee collection) by one set of on-board equipment in any vehicle.

- **Public Transport payment and ticketing:**

These services reduce some of the barriers to the use of public transport by making it easier to obtain tickets and pay for travel.

Common ITS Services are not considered to be essential and do not have to be available everywhere. However, they usually provide useful traffic information and management measures that can yield important benefits on a local scale. The services included in this category are the following:

- Dynamic route guidance
- Parking monitoring, information and guidance
- Personalised on-trip road information

- Intelligent Speed Adaptation
- Freight and Fleet management

Travel and Traffic Information Services according to TEMPO classification

As noted above, Travel and Traffic Information Services are included in both Minimum ITS Services and Common ITS Services. The two groups encompass various forms of TTIS addressing different transport modes and meeting fundamental user needs in different stages of travel.

TTIS within Minimum ITS Services group set

Pre-trip road traffic information service: A service providing the traveller with information before actually starting a trip by road (at home, at the office or in any other location as origin of a trip), on the actual and expected status of the network as it affects the proposed trip, independent of the country and road operators involved. All foreseen information relevant to the journey should be available.

The main characteristics of this service type are as follows:

- Pre-trip service used at the origin (e.g. at home, at the office)
- Service is used for a certain route thus the main “basic” service is route planning
- Service uses all types of dynamic traffic information for the road traffic like traffic flow information, traffic messages or road weather information
- Service uses real-time data about current and forecast network status
- Service should be available on all “common” end user devices for pre-trip information

Pre-trip public transport information service: A service providing the traveller with information before actually starting a trip (at the origin of the trip), based on timetables, and on the actual and expected status of the public transport services (all modes but in particular rail), independently of the operators involved. Key features include:

- Pre-trip service used at the origin (e.g. at home, at the office or a station)
- The service uses all types of dynamic public transport information (e.g. delay information) in combination with the static timetables
- The service uses real-time data about current and forecasted status
- The service should be available on all “common” end user devices for pre-trip information

Multi-modal trip planning service: A multi-modal service calculates the most efficient route and transport mode for the traveller to his destination before starting a trip, taking into account delays and the actual and expected status of the network. The service includes details about the expected time of arrival. The trip can cover different countries and infrastructure (e.g. road) operators. This service forms an integration of the two previous services on pre-trip road traffic information and pre-trip public transport information services. It is the final goal to be reached.

On-trip real-time road information service: A common service providing road users with real-time information on the status of the road network: incidents (cause and expected delays), congestion, travel times, delays, re-routing advice. The service provides the same information to all road users without personalisation.

The main characteristics of this service type are:

- On-trip service used on the trip “in-car”
- The service is used for a certain trip thus the main “basic” service is navigation
- The service uses all types of dynamic traffic information for the road traffic like traffic flow information, traffic messages or road weather information
- The service uses real-time data about current and forecast network status
- The service should be available on all “common” end user devices for on-trip and in-car services

Real-time passenger information: A service providing users at stops and on-board vehicles with information on the status of the public transport: next departure to destination, operating according to time schedule, delays. This service should be available to the public and free of charge. This service type describes a common public information service that is not provided on user request. This type of push-service has the same characteristics as broadcasting services where data are broadcast to the user independent of the users need for this information. The corresponding personalised service is defined as a common (paid) service. Key requirements of this service type include:

- On-trip service used on the trip “in-car” and at the stations.
- “Broadcasting” service without personalisation and reference to a certain trip.
- The service uses all types of dynamic public transport information.
- The service uses real-time data about current status.
- The service should be available on all “common” end user devices in public transport vehicles and on displays at stations and stops.

TTIS within Common ITS Services group set

Personalised on-trip road information service: A service providing the road user automatically (Push-service) with personalised information on incidents, congestion, delays or change in travel time and arrival time at destination. The service takes into account the planned route, the user profile, vehicle characteristics and the requirements and constraints of the user at that specific moment. The trip can cover different countries and road operators.

The main characteristics of this service type include:

- On-trip service used in the car
- The service is used for a certain route thus the main “basic” service is a pre-trip route planning but information occurring on the trip is not used to re-calculate the route (compare next service type)

- The service uses all types of dynamic traffic information for the road traffic like traffic flow information, traffic messages or road weather information
- The service uses real-time data about current and forecasted status
- The service should be available on all “common” end user devices for on-trip information
- Personalised service with user/vehicle profile

Dynamic route guidance¹: A service guiding the traveller efficiently to his destination taking into account the actual and expected status of the network and the user profile and vehicle characteristics. The service includes details about the expected time of arrival. The trip can cover different countries and road operators. Main features include:

- On-trip service used in the car
- The service is used for certain routes thus the main “basic” service is a dynamic route planning/navigation (The service is an extension of the previous service; the route will be re-calculated depending on the real-time traffic data/messages).
- The service uses all types of dynamic traffic information for the road traffic like traffic flow information, traffic messages or road weather information
- The service uses real-time data about current and forecast status
- The service should be available on all “common” end user devices for on-trip information
- Personalised service with user/vehicle profile

Parking monitoring, information and guidance: A service that monitors parking availability, guides users to available parking spaces, for pre-trip planning, on-trip information, personalised and real-time information. In the case of park-and-ride additional passenger information would be provided. The key characteristics of this service type are:

- Pre-trip service to plan a journey
- On-trip service (monitoring) used in the car
- Service includes route planning to the available parking space thus a “basic” service is dynamic route planning/navigation
- Service uses real-time data about current and forecast status of parking occupancy
- Service should be available on all “common” end user devices for pre-trip and on-trip information
- Personalised service with user profile

Personalised real-time passenger information: A service providing users with personalised real-time information on the status of the public transport. The service takes into account the planned trip, user profile and the requirements and constraints of the user at

1 Dynamic in-car navigation

that specific moment. The service can also include advice for public transport alternatives in order to optimise the overall travel time. The trip can cover different countries and operators. The case of international journey planning is considered in Section 2.5.

Key features of the service include:

- On-trip service (monitoring) used during the trip
The service includes dynamic public transport trip planning (dynamic re-calculation of public transport trip depending on current public transport status) and P+R-information
- The service uses real-time data about current and forecasted status of public transport
- The service should be available on all “common” end user devices for on-trip information
- Personalised service with user profile

Freight and Fleet management service: Vehicles requiring the service would register a vehicle, its load and the intended journey, together with the characteristics - high or wide vehicle, slow moving vehicle, valuable load, dangerous load, vulnerable load, need for escort, etc. The details of the load and journey would be checked against approved route restriction databases and amended accordingly prior to the start of the journey. When the journey started, the driver would “logon” to the service. The vehicle would then be tracked continuously and all the necessary support would be provided, particularly as regards:

- Traffic information especially for the freight traffic (e.g. restrictions in height and width)
- Tracking the vehicle on a journey and providing warnings of approaching weight/height restrictions

The characteristics of this service type are as follows:

- On-trip service (monitoring) used on the trip in the car
- The service includes dynamic road traffic information especially information regarding to heavy goods transportation (HGT)
- The service is used for certain routes thus the main “basic” service is a dynamic route planning/navigation for HGT.
- The service uses all types of dynamic traffic information for the road traffic like traffic flow information, traffic messages or road weather information
- The service uses real-time data about current and forecasted status of public transport
- The service should be available on all “common” end user devices for on-trip information
- Personalised service with vehicle profile

2.4.3 Reference service and value chain

The process of generating suitable information by different services and providing this to end users implies the co-operation among specific actors in the Travel and Traffic Information Service “value chain” (Figure 2.4).

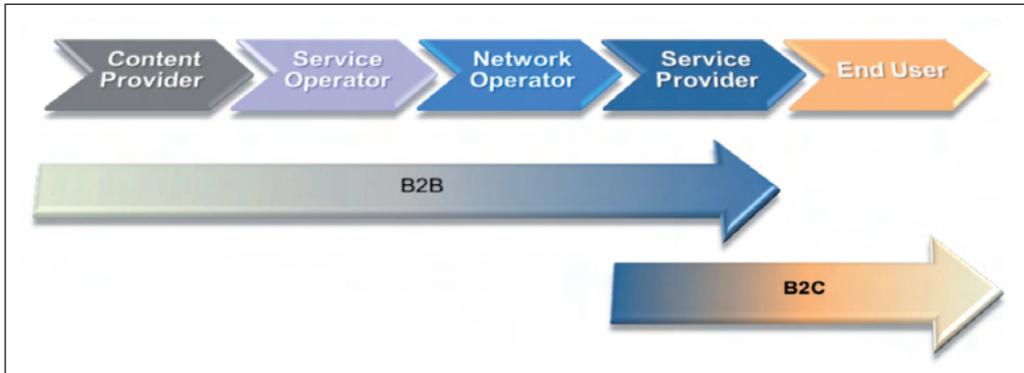


Figure 2.4: Value chain for traffic information

The source of all information services is a content owner or content provider who owns the content (e.g. traffic data) and/or provides the content for service application. A service operator uses this content to generate information with added value. The service provider is the interface to the customer. He publishes the service and is responsible for all marketing and contractual issues with the end user. In order to allow service providers to publish their services, network providers supply the needed communication network, like a mobile network or an internet access, etc.

A general outline of characteristics and roles of the different actors in the TTIS service and value chain can be given as defined, for instance, in eMOTION (2008):

1. **Content Owner/Provider:** At the beginning of the chain, multi-modal data platforms (content and information sources) can be operated by different providers (content owner and content providers) that can – but need not – be the same institution. For example the sources of traffic data are often operated by public authorities and administrations within Traffic Information Centres (TIC).
2. **Service Operator:** They are developing and maintaining the respective end-user traffic and transport related services. Typically they are private organisations running the service. They are mostly not directly visible to the end user.
3. **Service Provider:** Typically public or private (or public-private) entities providing their information services to the users of road and transport infrastructure on a free or commercial basis. They are usually directly visible to the end user.
4. **Network Provider:** They provide the necessary communication infrastructure through service related communication via Internet (ISP) or voice and mobile data links (e.g.

GSM, GPRS, UMTS, Radio Broadcast). They are typically private, profit oriented organisations.

5. **User:** Finally, end users are the consumers of the information services provided by the TTIS.

2.4.4 *The implementation technologies*

The implementation of modern TTIS involves a number of applied Information and Communication Technologies, including base communications technologies and infrastructures, data transmission protocols and formats, vehicle location, in-car devices and navigation technologies, geospatial data and digital maps, Internet applications, etc.

Data communications technologies

Data communications technologies represent the key enabler of any efficient Traffic and Travel Information Service provision. Historically, travel information services have exploited radio and television technologies. Radio systems have long been the backbone technology, with the **Traffic Message Channel** (TMC) becoming the most successful TTIS implementation from the mid 90s, reaching a very large coverage in Europe (Figure 2.5). TMC broadcasts real-time traffic and weather information using the FM Radio Data System (RDS), a special application of the radio spectrum allowing the transmission of small amounts of data over the terrestrial FM channels. Silently transmitted over the radio channel – i.e. without disrupting the normal audio transmission – data messages are received and decoded by a TMC-equipped radio and translated into the users own language. Furthermore, TMC data can also be received and decoded by on-board navigation devices offering dynamic route guidance, again in the users own language.

TMC is an ISO standard (ISO 14819) originally promoted and maintained by the TMC Forum (www.tmcforum.com) a non-profit organisation gathering together service providers, receiver manufacturers, car manufactures, map vendors, broadcasters (public and private), automobile clubs, public authorities and others. In November 2007, the TMC-Forum was merged into TISA (the Traffic Information Service Association; www.tisa.org) which has taken over all of its activities.

Beside the RDS system, TMC information can be transmitted over DAB (Digital Audio Broadcast) or satellite radio. DAB is a digital radio technology for broadcasting radio stations. DAB has become popular especially in Europe, and advocates of this technology highlight some advantage over analogue FM radio such as the capability of handling more stations in the same radio spectrum. However, the quality of transmission is generally less than with analogue radio; this was the case until the appearance of DAB+ in 2007, which has renewed interest in digital radio broadcast, with several European countries starting or planning to start DAB+ services shortly, including Italy, Malta, Switzerland, Hungary, Germany and the UK.

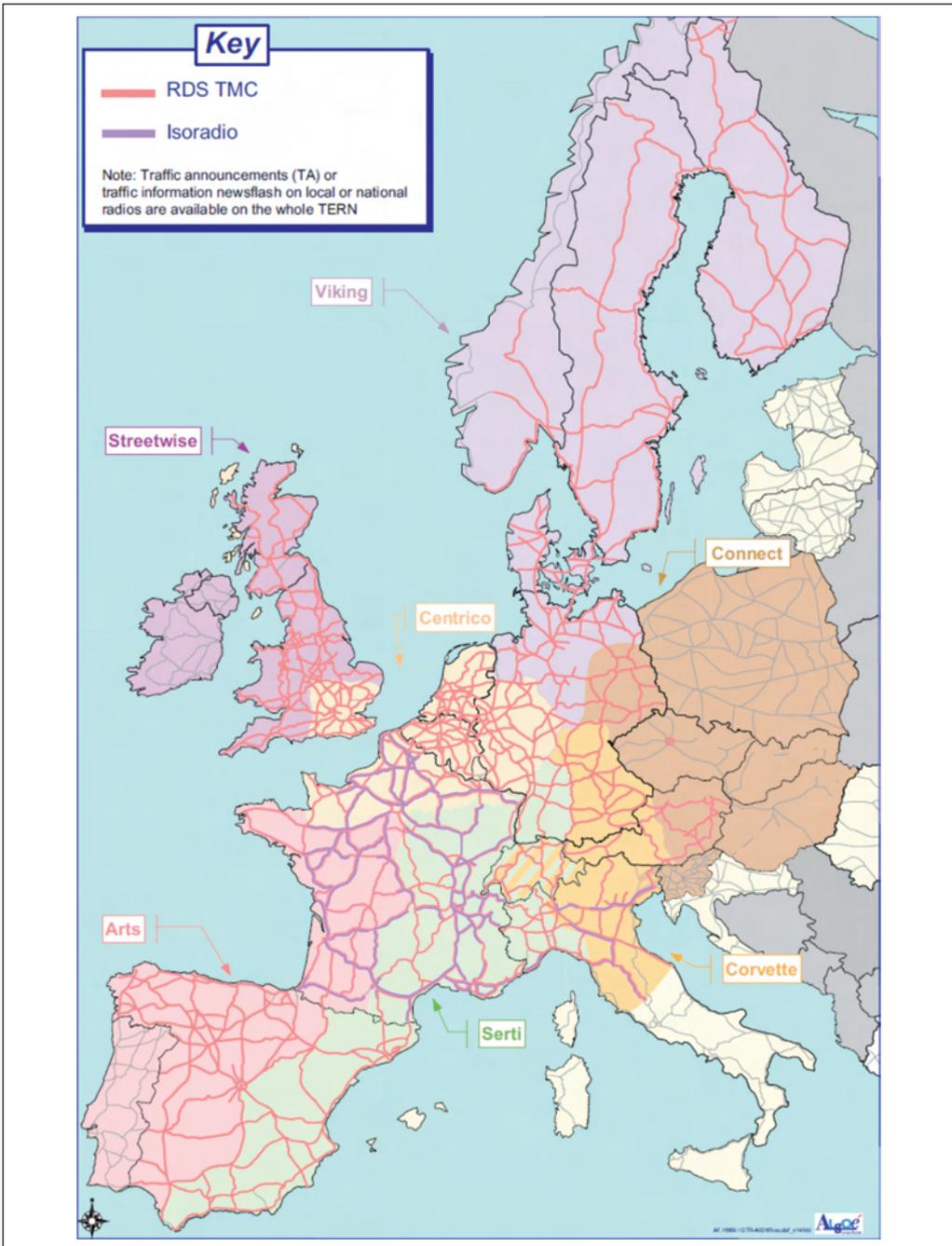


Figure 2.5: Traffic information radio and RDS-TMC deployment in Europe at the end of 2006 (from TEMPO, 2007)

The spread of 2.5G and 3G cellular phone technology and public telephone networks throughout Europe, together with the convergence of mobile Internet services, have also provided an alternative affordable infrastructure for the delivery of traffic and travel information and services. Nowadays, several commercial service providers are offering TTI services over cellular networks. Examples include TomTom[®] (www.tomtom.com) currently the world market leaders in digital mapping and routing information services, operating through a wireless data connection with a user's compatible Bluetooth cellular phone, Navigon[®] AG (www.navigon.com), WayFinder[®] (www.wayfinder.com), BeMobile[®] (www.be-mobile.be), Netbiscuits[®]/ADAC (wap.adac.de).

Vehicle location technologies

Vehicle location and positioning technologies are crucial elements of TTIS as they enable information filtering on the basis of the actual position of the vehicle and the provision of dynamic navigation as well as other Location-Based Services (LBS). Basically, two different methods are considered for positioning: (1) the vehicle calculates its position by itself, using wirelessly received signals and/or on-board sensors, or (2) the position is calculated off-vehicle, e.g. in the operator's control or service centre, from signals sent by the vehicle. With the increasing capabilities of on-board devices and the rapid growth of the personal and in-car navigation applications market, in-vehicle calculation of position and selection of TTIS transmitted information based on computed co-ordinates or location coding techniques is by far the prevailing method today.

Satellite positioning is currently the most widely used technique. GPS (Global Positioning System) is currently the most used and has an accuracy of about 10 metres in open spaces. The GPS system is managed by the United States Air Force, but is free for civilian use. GPS satellites are in medium earth orbit and there are currently 31 satellites in operation. User GPS receivers calculate the position by triangulation methods based on the actual measured distance between the receiver and three or more satellites. GPS chipsets, like e.g. SiRF Star III, allow integrating satellite positioning receivers in mobile devices. Commercial GPS receivers send the data either through serial connection, USB or Bluetooth.

GALILEO is Europe's initiative for a state-of-the-art Global Navigation Satellite System (GNSS) providing a highly accurate, guaranteed global positioning service under civilian control. While providing autonomous navigation and positioning services, GALILEO will at the same time be interoperable with GPS and GLONASS, the Russian global positioning system. With a single receiver the user can calculate its position using any of the satellites in any combination. GALILEO will offer both an open service, with horizontal accuracy of about 4 metres (for dual frequency receivers), and an encrypted higher bandwidth Commercial Service with accuracy of better than 1 metre. By guaranteeing service availability, the system is suitable for safety crucial applications, such as (more)

automated operation of vehicles and the use of geographical data for IVIS (integrated vehicle safety) applications. The fully deployed GALILEO system will consist of 30 satellites and the associated ground infrastructure. It should be operational by 2012, four years later than originally anticipated.

Positioning using communication networks (cellular communication networks, WLAN networks) is an alternative method to satellite based location. The position is calculated using cell information and other information (e.g. time to arrival, signal strength) to determine the position of the vehicle. The accuracy depends on the network cells density, and is therefore much lower than satellite positioning, especially in rural areas. The communication cost for each position request is also a disadvantage.

Finally, position techniques are also available using beacons (e.g. RFID beacons, either installed roadside or in-vehicle). These technologies require rather high infrastructure costs, and are not flexible to changes in route planning. For these reasons, they are still quite uncommon today

Digital maps and geographical data

Geographical and spatially related data represent the base information for TTIS operation. Data and information related to the user location, the traffic situation, traffic and travel related events, any resource of relevance for the travel (Point of Interest, POI) – such as road infrastructure elements, transport facilities like e.g. train stations, public transport stops, parking facilities, etc. – are all spatially and geographically related, and knowledge about their spatial location on a map is crucial for travel planning and operation.

Digital maps provide electronic data store and accurate visual representation of geographic and spatial data against digitally rendered maps of a given territory (Figure 2.6).



Figure 2.6: Digital maps showing street network and Point of Interest information (underground stations in London); Copyright Google Maps and Teletlas

Computer programs and applications provide map views from space and street level of much of the world, for both standalone desktop, Personal Navigation Devices (PND) or in-vehicle applications (see below) as well as for on-line access and use through the Internet and its standard technologies (i.e. web browsers, etc.). Google Maps (<http://maps.google.com>) is by far the most notable and largest internet-based application developed in the last few years, with free and commercial on-line access and a very large and growing community of users and developers.

End-user devices

TTIS information and services can reach and can be used by the target users through a variety of channels and end user devices. These tend to fall within two broad categories: (1) devices meant for pre-trip and post-trip information and services, which are accessed and used mainly from fixed locations (e.g. at home, in the office, on-street at fixed places, etc.) and (2) on-trip devices, i.e. devices for use on the move providing continuous access to dynamic and updated travel and traffic information and services.

The first category comprises mainly Internet-connected PCs, using high speed communications links (e.g. ADSL, SHDSL) and standard-sized PC screens for access to the information and services. Information kiosks or information screens are another type of fixed location TTIS user devices. These are on-street public terminals that offer web-based services and are typically used for pre-trip or on-trip (e.g. at bus stops, railway stations, etc.) information during multimodal journeys.

In-car telematics systems are either mobile portable devices or fixed/installed on-board devices, typically using GPS for positioning. They can be used for all on-trip services and are in particular applied for route guidance including dynamic route guidance based on broadcast traffic information, e.g. via RDS-TMC. Figure 2.7 below shows sample in-vehicle TTIS devices currently available on the market.



50 Figure 2.7: In-car navigation devices: (a) Blaupunkt TravelPilot EX V and (b) Garmin Nüvi

Mobile Internet devices – such as Personal Digital Assistants (PDA), Personal Navigation Devices (PND) and Smart Phones – can also be used for pre-, on- and post-trip information services. Today PDA/PNDs use the Cell-Id or a GPS receiver (integrated, via Bluetooth or wired connection) in order to gather the position of the device. Data exchange is realised by means of GPRS/EDGE, UMTS/HSDPA, or eventually WiFi accessed through a WiFi chip integrated in the PDA. These communication links can be used for all data updates necessary during a journey to get real-time information on traffic situations and public transport timetables.

The dramatic growth of 3G telephony in the last few years is certainly a major driver for the market of TTIS information and services distributed via mobile personal devices. Indeed, the personal navigation applications market has clearly benefited by this growth of enabling technologies and services. Thanks to the strong competition of major 3G handsets producers such as Apple, Nokia, Blackberry, HTC, LG, a number of mapping and navigation service providers such as TomTom®, Wayfinder® and Navigon® have started to release their services also on advanced 3G devices such as, for example, Apple's iPhone®, Blackberry® and Nokia 6110 smart phones (Figure 2.8).



Figure 2.8: Navigation services delivered on 3G devices: (a) Garmin's Nüvifone G60, (b) Apple's iPhone (with Navigon AG navigation software), (c) Blackberry

2.4.5 *Service standards and interoperability*

The definition of appropriate standards for TTIS, the search for consensus around such standards and their adoption have always been main concerns and activities in this area of Intelligent Transport Systems. Standards address different aspects and levels of the processes related to TTIS provision, from data models to communications protocols, the format of the exchanged data, the type of location referencing, etc.

The relevance of the issue for TTIS should be immediately clear: TTIS service provision involves a number of actors – from information producers and owners, to information integrators, TTIS service providers, communication service providers, up to the end users with their in-car or personal mobile devices – that are to integrate their operations in an optimal way within the global TTIS “value chain”, in order to achieve efficient and effective service provision, access and use. Furthermore, the geographical dimension of TTIS adds a further need for integration and interoperability, as information services require interconnection and interaction of several actors and service centres from the local (e.g. urban) level, to higher and more extended levels, such as regional, national and cross-border levels, up to full Pan-European service provision.

Pushed by international standardization bodies such as ISO, CEN and W3C, particularly through their working groups on ITS and TTIS applications, TTIS standards are an evolving field which depends on many factors, on the dynamic and evolution of technologies, regulations and relevant market sectors such as car industry, electronics and telecommunications. A recent analysis of the main standards in the field has been carried out within the European project eMOTION (eMOTION, 2006). In the remainder of this section, we will only provide a brief reference to the main relevant standards for TTIS systems as given in eMOTION (2007).

Private traffic information

Private traffic information is a TTIS application area where the development of standards has been most active, due to the relevance of the area, the importance of data exchange over large geographical areas (major European traffic corridors, trans-border co-operation, etc.) and the direct interests of the car industry.

The use of a standardised road network data model is obviously a key issue to enable interoperability, for instance, between traffic information sources (e.g. a road traffic events database operated by a Public Authority) and a navigation service (by e.g. a commercial service provider). **GDF** (ISO 14825) is an international and widespread standard with an extensive, high quality database offered by two leading commercial vendors, which is the basis of nearly all navigation applications worldwide.

DATEX is a traffic and travel data exchange mechanism, designed and developed by a European task force set up to standardise the interface between inter-regional Traffic Control Centres. The main aim is to allow the easy and efficient communication of traffic

and traveller Information. In its current version **DATEX 2** (DATEX 2, 2008) provides up to date and easy to use technology to exchange data, with a scalable set of interoperable profiles. The core data model includes all elements necessary to convey traffic and travel information to road users, including traffic flow data, traffic events, accidents and incidents, weather information, location referencing of all relevant information, etc. DATEX 2 is conceived to be preferably implemented on top of standard Internet protocols using standard technologies such as XML, HTTP and web services.

Data exchange over radio channels is based on the widely adopted **RDS-TMC** standard previously mentioned, defined as ISO standard 14819. RDS is a standard from the European Broadcasting Union (EBU) for sending small amounts of digital information using FM radio broadcasts. TMC is used to deliver traffic and travel information to the drivers using RDS. Messages are coded using the **Alert-C** protocol and are received by in-car RDS radio sets, that are able to automatically decode them to announce the correct information for the driver on the radio display. Navigation systems are also prepared to receive RDS-TMC information and use it for better trip planning. The standard is available at ISO and all local organizations in every country which are members of the ISO organization. Translations for the CEN – English are available at the TMC Forum's web site (TMC Forum, 2003).

TPEG (Transport Protocol Expert Group; see TISA, 2009) is an emerging standard promoted by the EBU including the specifications for transmission of language independent multi-modal Traffic and Travel Information. TPEG is designed for advanced traffic and travel information over a digital bearer e.g. Digital Radio (DAB), Digital TV (DVB) and the Internet; it is partly based on, and evolves from, the TMC standard, TPEG data being understandable by both machines and humans. Overall, TPEG specifications are defined in the ISO standards 18234 and 24530: the ISO/TS 18234 series specifies a binary format to exchange traffic and travel information; ISO/TS 24530 (tpegML) covers the data exchange in XML format. TPEG specifications broaden the scope of traffic and travel information data transmission beyond private traffic; indeed, it includes road traffic messages (TPEG-RTM) and public transport messages (TPEG-PTI) and, in future, are likely to include parking information, congestion and travel time information, and weather information. TPEG-LOC is the location referencing system (see below) used within TPEG.

Public transportation information

The standards relevant for the public transport information domain provide specifications of data formats and data exchange protocols specially designed for public transport applications.

Transmodel is an ISO (pre-)standard (rev. ENV 12896) which provides a thorough and detailed specification of all data models of interest for the interoperability of public

transport-related ITS applications. Transmodel version 5.1 standardizes the definition and modelling of relevant Public Transport related data aiming to build a reference for the variety of applications and systems in this domain (TRANSMODEL, 2001). A few examples are on-street and in-vehicle systems delivering information for passengers, web-based services for trip planning, booking, information etc. or systems run by public transport operators such as planning and scheduling systems; driver and vehicle rostering; fares management, AVM systems etc.

SIRI, the Service Interface for Real Time Information (SIRI, 2008) specifies a European interface standard for exchanging information about the planned, current or projected performance of real-time public transport operations between different computer systems. SIRI has been built by a European consortium of equipment suppliers, transport authorities, transport operators and transport consultants from CZ, D, DK, F, NO, SE and the UK with the backing of VDV in Germany, the Direction des Transports Terrestres of the French Ministry for Transport, and RTIG in the UK. The aim of SIRI was the inclusion of the best elements of various national and proprietary standards in Europe. It is realized using an XML schema, TransModel terminology and modelling concepts.

Other relevant standards include: **TransXChange** (TransXChange, 2008), a UK de facto standard for the exchange of bus route and timetable information; **IFOPT**, Identification of Fixed Objects in Public Transport (NAPTAN, 2008); a draft CEN standard, prCEN TS 278207 Public transport, defining a model and identification principles for the main fixed objects related to public access to Public Transport (e.g. stop points, stop areas, stations, connection links, entrances, etc.). Based on the previous standard **NaPTAN**² (NaPTAN, 2008) and on Transmodel, it can be used for bus stops, stations, airports, ferry ports and other transport interchanges, and includes accessibility data; **RailML** (RailML, 2008) designed for data exchange between rail operators, mainly focusing on the operation of trains and providing information about the infrastructure, the equipment and services of the rolling stock and the timetable necessary for travel information systems.

Location referencing and Location Based Services

Location referencing standards are of main relevance to ensure the location of any traffic information (data, events, etc.) is handled in a compatible way by different interacting systems and services; for instance, to ensure that the data (message) related to a traffic accident generated by a Traffic Information Centre is correctly understood (i.e. located)

2 NAPTAN, National Public Transport Access Node Database, a de facto standard used to model all the points of access to public transport (i.e. bus stops, stations, coach terminus, airports, ferry terminals, etc.) in the UK. The NaPTAN database is maintained centrally by the Department for Transport.

by a commercial service provider delivering routing and real-time traffic information or other Location Based Service (LBS) to its subscribers.

All TTIS related data modelling and transmission standards previously described involve some form of Location Referencing Methods (LRM) that can be used to describe locations in a network or otherwise on the surface of the earth. Such methods can be used to locate transport-related objects (i.e. data, events, etc.) and to allow interpretation of location information by both an encoding and a decoding system. Locations can take the form of points, lines (e.g. route segments or sequences) or areas (e.g. sub-parts of a road network).

The **ISO 17572 series** provides (abstract) specifications of **generic** LRM methods for geographic databases in ITS applications. Detailed definitions are provided of what is meant by location referenced objects, including whether or not components of the reference are mandatory or optional, and their characteristics. The **ISO 19133** standard provides **linear** location referencing for routing and navigation applications (see below). It defines point-like locations by referencing linear network elements of a specific network and specifying the arc length from a reference point on the linear geometry, where the referenced location is situated. Additionally a lateral offset may be given.

RDS-TMC makes use of the Alert-C database of pre-coded locations (usually, nationwide for the EU countries implementing RDS-TMC services). TPEG uses **TPEG-Loc**, which supports all the common methods mentioned in ISO LRM 17572 and provides not only a point position and expansion, but also the language aware textual descriptions of the area.

The use of predefined locations (location coding, as used e.g. in Alert-C) is the most common method. However, more recently the capability of supporting **dynamic location references** – i.e. the ability of referring to locations ‘on the fly’ without the need of having a database of locations predefined in advance – is a major concern for TTIS applications such as navigation and other mobile traffic related services. **AGORA-C** (ISO 17572-3 specifications) is designed for dynamic location referencing between client and server map databases from different suppliers, and has the ability to describe Points, Linear locations, Implicit Areas and Explicit Areas. It is the emerging standard in the field, supporting (a) dynamic location referencing, and (b) independency from the particular maps used; i.e. applications are able to correctly encode/decode location-based objects without knowing which particular map database is stored in the device to be used to present the information to the user. This is seen as a major enabling technology and a main driver to boost commercial dynamic navigation applications and services. It will facilitate, for instance, the distribution of TPEG traffic information related to any point in the road network to a wide range of users and devices such as navigation systems, PDAs and smartphones, without requiring a pre-coded list of potential locations to be stored or updated in the devices.

OpenGIS® standards (OGC, the Open Geospatial Consortium³) support interoperable applications that “geo-enable” the web, wireless and location-based services, as well as ICT applications in various fields. Such standards enable technology developers to make complex spatial information and services accessible and useful with all kinds of applications. **OpenLS** (OGC-OpenLS, 2005) the OpenGIS® Open Location Services Interface Standard, is a main reference in this area, allowing description of locations as Addresses, POIs or generalised geometric Positions. It specifies interfaces enabling companies in the LBS value chain to ensure interoperability of their applications. Relevant applications include, for instance: traffic information services, personal navigation services, proximity services, emergency services, location recall, mobile field services, travel directions, restaurant finder, corporate asset locator, etc.

Along the same lines, the interest in open industrial standards for location referencing is leading to other developments in the area, such as **OpenLR™**, the open standard for encoding, transmitting and decoding location references in digital maps applications, recently (summer 2009) launched by TomTom® (OpenLR, 2009).

Finally, flexible location referencing methods are also defined, allowing the use of various schemes within the same standard. DATEX 2, for instance, uses a flexible location referencing, which can accommodate ALERT-C, TPEG-Loc as well as co-ordinate location referencing.

Routing, navigation and public transport journey planning

Routing, navigation and journey planning – addressing either or both private and public transport modes – are among the most popular end-user TTIS applications and services. The need for standards in this area should be evident, a proper and effective interaction between data providers (mainly public) and commercial service operators being a main critical element of the service generation and provision chain.

ISO 19133 is the reference ISO standard defining the data types, and operations associated with those types, for the implementation of tracking and navigation services (ISO 19133, 2005). It is designed to specify web services that can be made available to wireless devices through web-resident proxy applications, although it is not restricted to that environment. ISO 19133 uses a Linear Referencing System, i.e. a reference system in which features are localised by a measure along a linear element (e.g. Km x on route segment y) and provides a fully-fledged specification for a Navigation Service for finding optimised routes through a network under constraints. Building on ISO 19133,

3 The Open Geospatial Consortium (www.opengeospatial.org) is an international, no-profit open industrial consortium federating over 380 worldwide players (companies, government agencies and universities) in the area of geospatial information and providing a number of open standards in the field, particularly in the area of web technologies.

ISO 19134 defines a model for multi-modal (in the sense of inter-modal) routing and navigation (ISO 19134, 2007).

In the area of public transport journey planning the definition and adoption of standards that would allow interoperability of different journey planners and the planning of journeys across different regions is still an issue (see e.g. Section 2.5, Decision Support for Trip Planning). Some relevant developments in this area have been undertaken mainly in the UK, with definition and nation-wide adoption of **JourneyWeb** (JourneyWeb, 2006; JourneyWeb, 2008) showing the main directions for development of a Pan-European journey planning infrastructure.

JourneyWeb is an XML protocol to allow different (and distributed) journey planning engines to communicate with each other in order to provide multi-modal journeys spanning different regions. It is a UK national *de facto* standard sponsored by the UK Department of Transport that has been used in several applications, the most relevant being the Transport Direct Portal⁴ providing contiguous distributed journey planning for the whole of the UK and accessible also by mobile devices (smartphones). Being an open system and platform independent protocol, JourneyWeb builds on two other standards: NaPTAN (NaPTAN, 2008) and the National Public Transport Gazetteer, NPTG (NPTG, 2008) providing a topographic database of towns and settlements in the UK.

2.4.6 Concluding remarks

Multi-modal Travel and Traffic Information Services define a main class of ITS services – with different goals, aspects and implementations – and a strategic element for the implementation of the Trans-European transport and traffic infrastructure in the years to come.

TTISs can address different transport and traffic modes – from car traffic, to passenger services, freight transport and logistics – different transport environments – urban, peri-urban, interurban – and scales – regional, national, cross-border, etc. Usually, they provide information and services in two main phases of the travel: (a) pre-trip, when the best decisions are required to plan the travel in an optimal manner prior to its actual start, and (b) on-trip, when informed decisions are to be taken to complete the travel facing the actual traffic and transport conditions and events.

The design, deployment and operation of multi-modal TTISs and applications address a complex field where several issues are to be considered in an integrated way, from the different user needs and requirements related to the different targeted end-user categories, to the implementation technologies and standards, the various actors involved in the service production chain and their interests, the background public objectives to be preserved, the commercial and market drivers, etc.

4 <http://www.transportdirect.info/>

Acknowledgements

The work presented here draws partly from the work and results obtained in the eMO-TION project, part-funded by the European Commission under contract No. FP6-TREN-019939-SUSTDEV.

2.5 Decision support for trip planning

K. Zografos, K.N. Androutsopoulos

Planning an urban, regional, national, or international trip constitutes a complex decision faced by many travellers especially those unfamiliar with the relevant urban or interurban transportation services. The objective of this type of decision is to determine the optimal itinerary from an origin to a destination according to the traveller's preferences, utilising the relevant available transportation services.

The primary difficulties encountered by a traveller for this type of decision relate to: *i*) the lack of information regarding the schedule and the routes of the public transport services from a single point of access, and *ii*) the pertinent intensive task of determining and assessing alternative feasible itineraries in the dense urban, interurban, and/or international transportation networks. In this context, many advanced public transport information systems were developed during the past decade, offering trip planning services for local or regional trips (Peng, 1997; Casey et al, 1998). Recently, trip planning services are offered to the travellers through on-line web-based applications (Rehrl et al., 2007; Lo et al., 2005; Peng and Huang 2000), information kiosks at terminals, and voice portals (Zografos et al., 2009).

The objective of this section is to present the needs of the travellers for decision support in planning their trip and the major features of the existing trip planning systems. The remainder of this section is organized as follows. In section 2.5.1 there is a presentation of the features of the trip planning problem, while section 2.5.2 provides an overview of the travellers trip planning needs drawing on work completed in the FP7 WISETRIP project. Section 2.5.3 presents an overview of the functionalities of selected existing trip planning services and provides their major features. Section 2.5.4 presents the major trip planning information delivery technologies and section 2.5.5 provides the directions for future research and developments regarding trip planning services.

2.5.1 Trip Planning Problem

Any conventional public transport service is defined by a sequence of stops traversed by a vehicle at scheduled points in time on a fixed route. Thus, planning any trip involves the determination of a sequence of alternate route segments of public transport services connected with transfer links, which forms an itinerary from the origin to the destination

of the trip⁵. In the case of an urban trip the transfer link may simply involve walking from one stop to another. In the case of a regional or national trip any transfer (i.e., between two stations, between the location of origin and the first station, or the final station of the trip and the location of destination) is realized by an urban trip (performed either by walking or public transport). Similarly, any transfer within an international trip may involve any of the following: walking, an intermediate urban trip, or an intermediate regional trip. In any case however, the associated trip planning problem involves the determination of the optimal path in a multi-modal transportation network along with the schedule of traversing it (Zografos and Androutsopoulos, 2008). Any such path enhanced with a feasible schedule, is called itinerary. It is evident that any trip may be realized by several alternative itineraries.

The urban trip planning problem usually involves the determination of the itinerary within an earliest departure time and /or a latest arrival time that optimizes one of the following: the total travel time, the number of transfers, and the total transfer time. The international/ national/ regional trip planning problem aims at the determination of the entire set of alternative itineraries in a multi-modal international/ interurban public transportation network that depart within an earliest and latest departure dates and times.

The alternative efficient interurban itineraries are assessed and ranked in terms of travel time, number of transfers, total transfer time and monetary cost. Note that apart from a sequence of international and/or interurban transport services, each feasible interurban itinerary might also include an urban itinerary for each constituent transfer link. The earliest departure time for any of these intermediate urban itinerary planning problems is equal to the arrival time of the preceding interurban transport leg and the corresponding latest arrival time equals the departure time of the subsequent interurban transport leg (see Figure 2.9).

Note also that similar intermediate urban trips may also arise for accessing the first terminal of the national/international trip or for getting from the last terminal to the point of destination.

2.5.2 Trip Lifecycle and Associated Planning Needs

Different types of decisions are made at different stages of a trip. In this context, trip planning needs vary according to the stage of the trip lifecycle. In general, the lifecycle of any trip can be decomposed to three phases: i) the pre-trip phase, ii) the trip execution phase (sometimes referred to as the “en route” phase) and iii) the post-trip phase. The pre-trip phase refers to the time period between the time that the need of the trip

5 In the remainder of this chapter, when “trip” is not explicitly specified it refers to any type including urban, regional/ national, or international.

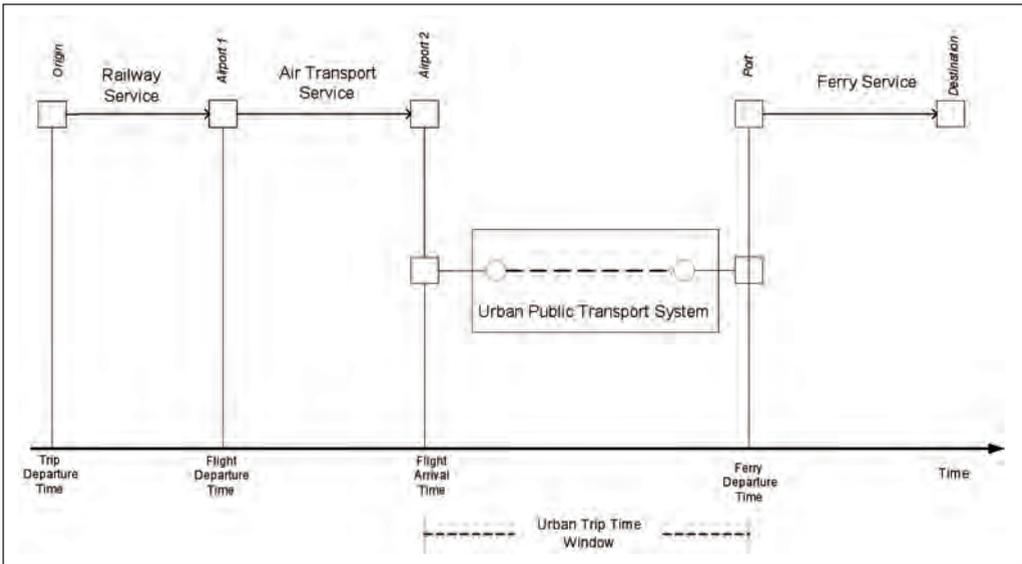


Figure 2.9: A diagram representing the itinerary for an international trip, highlighting the planning constraints (earliest departure- latest arrival times) for the intermediate urban trip

arises and the time that the traveller commences his/her trip (i.e., leaves the location of origin). The execution phase of the trip refers to the time period between the time that the traveller leaves the location of origin until the time that he/she reaches the location of destination. Finally, the post-trip phase refers to the time period after the time that the traveller reaches his/her last terminal/stop of his/her trip or the location of destination. Moreover, the pre-trip and trip execution phases could be further decomposed to intermediate stages due to the different information needs of the traveller in each of them. Thus, each of the above phases can be further broken down to the following stages:

- Pre-trip Phase
 - Planning Stage: this stage involves planning the entire trip and booking the tickets for any segments of the trip (if such an option is possible or mandatory).
 - Awaiting Trip Commencement: this stage refers to the period defined from booking the ticket(s) (or finalizing trip planning) until the time that the traveller is about to commence his/her trip (according to the relevant travel plan).
- Trip Execution Phase
 - Waiting stage: this stage refers to the time period spent by the traveller waiting at a stop/terminal for embarkation
 - On-board stage: it refers to the period that the traveller is on-board a vehicle of a transport service.

- Transfer stage: it refers to the part of the trip in which the traveller transfers from one stop/terminal to another, from the location of origin to the first stop/terminal of the trip, or from the last terminal/stop to the location of destination.

Figure 2.10 illustrates the proposed trip lifecycle model and its association with the major events of a trip.

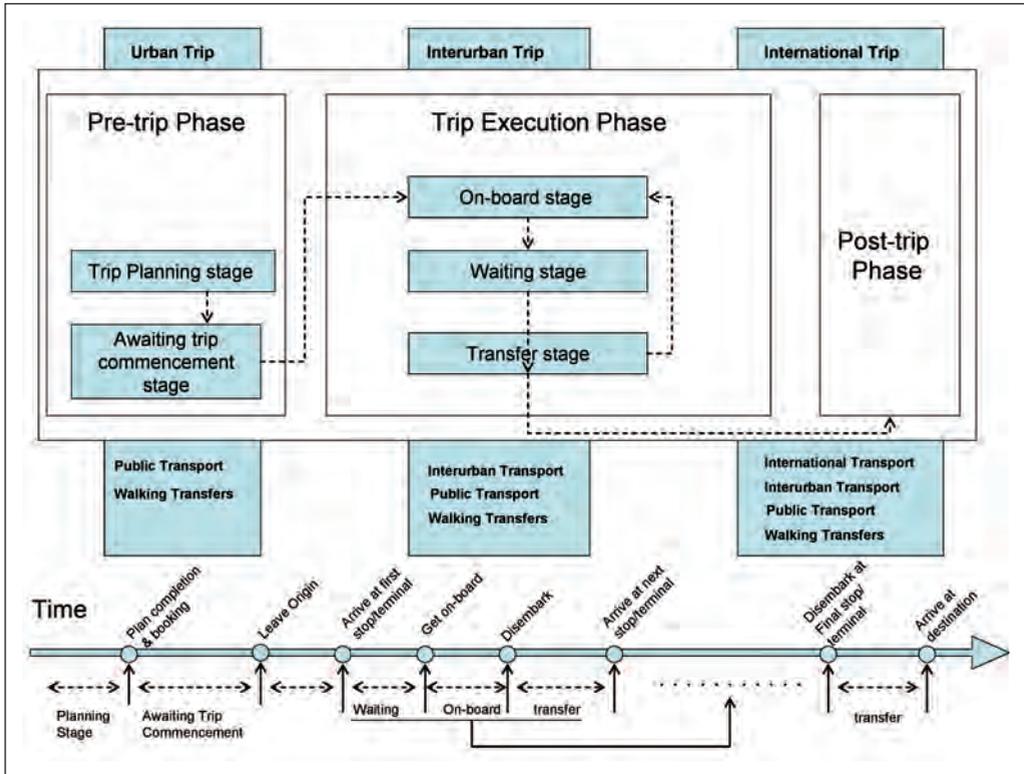


Figure 2.10: Major categories of information needs and services that could be integrated in WISETRIP (source: WISETRIP, 2008)

Traveller decision support needs may differ for each of the above phases/stages when customised for the three major categories of trips (i.e., urban, national, international). In general the following remarks can be made about the travellers' information needs in each of the trip lifecycle phases:

- The frequency of the transport services in an urban public transport system is much higher than the corresponding frequency for the interurban and international transport services. Therefore, the travellers show more flexibility and have less expectation for accuracy for the time plan of an urban itinerary than for the corresponding time plan of national/ international

trip is by far more important for the traveller than the corresponding stage for the urban trip.

- The average waiting, on-board, and transfer times of an urban trip are usually much shorter than the corresponding times for a national or international trip. Thus studying the provision of real-time trip re-planning at each of the separate stages of the trip execution phase is applicable for the national or international trips rather than the urban trip.

The availability of comprehensive and accurate information for trip planning can engender knowledge and confidence, foster positive attitudes towards the service provider and create favourable perceptions of efficiency and security. Indeed, information has become such a vital commodity that one can argue that informed travellers are the key to successful future transport service provision. One of the responses to the need for informed travel planning and execution has been the development of advanced passenger information and trip planning systems covering the entire trip lifecycle. Nowadays, the deployment of the internet and wireless information and communication technologies have enabled the development of Internet-based trip planners for facilitating travellers in planning their travel decisions (Peng and Huang, 2000).

In the analysis that follows the determination of the trip planning information needs for each type of trip and stage of the relevant trip lifecycle is based on the identification and assessment of the strengths and weaknesses of relevant existing journey planners. In general, providing door to door travel information contributes to the decrease of a trip inconvenience. Moreover, a door to door multi-modal journey planner may decrease the time and the cognitive effort needed by travellers for searching and acquiring information for planning a trip (Grotehuis et al., 2007). A literature review of existing studies referring to the travel information needs and services provided by passenger information systems (Molin and Timmermans, 2006; Caufield and O'Mahony, 2007; Rehrl et al., 2007; Zografos et al, 2009; Zografos et al., 2008) signified that no international door to door multi-modal trip planning services were identified among the systems surveyed by the authors as part of the FP7 WISETRIP project. To be more specific, the journey planners covering international trips involve either a single mode, or they only cover trips to neighbouring countries (WISETRIP, 2008).

Interchange between modes is critical for any type of trip (urban, national, or international). An anxiety over interchange is created to the traveller since arriving late at the next stop or terminal might disrupt the entire trip (Lyons and Harman, 2002; Hine and Scott, 2000). In this context, providing accurate and comprehensive information over the interchange between two consecutive hops (especially for the traveller who is unfamiliar with the specific interchange connections) constitutes a significant information need for the travellers.

Availability of fare/ ticket information is very limited in the existing journey planners since it is only provided for specific transport services. Moreover, limited ticket booking is encountered (only for single mode) within the existing journey planners that participated in the survey. However, estimates for the cost and time of a trip is critical information in the trip planning or re-planning process. Thus, a trip planning service should provide the user with alternative trip itineraries (especially for regional and international trips) making clear the cost-time trade-off of alternative trip options.

Travellers that use public transport (for urban, national, or international trips) feel insecure with regards to the trip execution since they are not in control of the trip, as in the case of car use (Lyons and Harman, 2002). This issue could be addressed by the provision of detailed information regarding the trip itinerary before the trip and en-route. The travel information needed during waiting at the stop/terminal mainly aims at supporting the secure and efficient execution of the planned trip. The traveller is usually familiar with the travel up to the first stop/terminal of the trip. On the other hand a traveller (especially national and international traveller) may be most probably unfamiliar with the layout of the remaining intermediate stops (including the destination), facing difficulties in finding his/her way during transfers (Dziekan, 2008).

Another major concern for the travellers relates to the unexpected disruptions of the transport services (in any type of trip). In this respect, apart from notifying the traveller for any transport service disruption affecting their trip, it is imperative for a journey planner to provide the user with alternative feasible travel plans as close as possible to the users preferences and aligned with the initial scheduling constraints (e.g. latest arrival time).

2.5.3 Trip Planning Services

Most of the existing Internet-based passenger information systems cover urban and/or interurban trips by providing static information (i.e. routes, schedules, and fares) and trip planning services. In particular, many metropolitan public transit organizations have deployed urban trip planners, e.g., Athens-OASA (<http://www.oasa.gr/?tml=1&pageid=90&menu=2&pg=1>), Calgary Transit (<http://tripplanning.calgarytransit.com/>), Vancouver Translink (<http://www.translink.bc.ca/default.asp>), San Francisco Bay Area-511 (<http://transit.511.org/tripplanner/index.asp>), Washington Metropolitan Area Transit Authority (<http://www.wmata.com/>), which aim to identify the itinerary that departs or arrives at a given time and minimizes one of the following criteria: en-route time, number of transfers, or the walking time. On the other hand, the existing interurban journey planners involve the provision of alternative trip plans for either a single mode, e.g., CityRail in Sydney (http://www.cityrail.info/fares/trip_planner.jsp), UK National Rail (<http://ojp1.nationalrail.co.uk/en/pj/jp>), or multiple modes, e.g., Transport Direct (<http://www.transportdirect.info>) covering national level trips in United Kingdom and

Journey.Fi (<http://www.journey.fi/>) partially covering the national trips in Finland. Major limitations of the above multi-modal trip planning systems relate to: i) the limited number (e.g. up to five) of alternative itineraries offered to the user for a given trip, ii) urban itineraries are offered solely for realizing intra-urban transport mode connections, iii) no real-time en-route information or alert is provided to the users.

The major features relevant to the trip planning services offered by existing journey planners are the following:

- i) **Geographical coverage.** Nowadays internet-based journey planners offer trip planning services for urban, regional, or national trips. International journey planners basically cover trips between neighbouring countries or they cover a single transportation mode. International door-to-door journey planners covering multiple modes of transport are currently envisaged at EU research level (WISETRIP, eMOTION, iTRAVEL).
- ii) **Mode type covered.** Two major categories can be identified under this feature: i) single mode journey planners, and ii) multi-modal journey planners. The former type of journey planners offers to the user the schedule and routes of the relevant urban or interurban transport services provided through a single mode and trip planning services aiming at specifying alternative itineraries for a given trip request. On the other hand the latter type of journey planners provide the above type information services combining transport services of different transport modes.
- iii) **Itinerary Assessment Criteria.** Trip planning services aim to provide one or more itineraries associated with a trip request. The most common criteria used in order to determine the optimal itinerary or assess and rank the alternative itineraries for a given trip request include: i) the total travel time, ii) the number of transfers, iii) the total transfer (walking) time, and iv) the total monetary cost. Combinations of the above criteria are also used in terms of assessing and ranking alternative itineraries. Recently a lexicographical ordering approach has been used in order to identify the optimal itinerary for urban trip planning problems considering multiple criteria (Zografos and Androutsopoulos, 2008)
- iv) **Transfer Guidance Information.** Providing special routing functionalities for performing transfers between transport services or between the final stop and the location of destination constitutes an additional trip planning feature, valuable for travellers unfamiliar with the underlying transportation services. This type of service includes the detailed description of the transfers in a trip making reference to the underlying street network or the building layout (in case the traveller has to move within a large terminal or complex of buildings). Map-based information may also be provided in order to guide the traveller. This type of functionality is mostly ap-

preciated for the last part of the trip (urban, national or international) where the traveller has to move to the final destination point by walking (e.g. the traveller has to move from the metro station to his/her hotel).

- v) Booking Capabilities/ ticket availability. An alternative means to direct ticket booking through a journey planner relates to the provision of web links to the relevant site where booking for each transport leg of the trip is possible.
- vi) Multi-lingual functionality referring to the provision of the itinerary description and the trip request formulation through the native language of the user. Most of the national, regional or urban journey planners use English as an alternative language.
- vii) En-route re-planning, referring to the functionality providing the user alternative feasible itineraries from the current location (anywhere within his/ her trip itinerary) in alignment with the initial itinerary in the case that the current travel plan becomes infeasible. This type of functionality implies that a real-time alerting mechanism is present in the journey planner checking for the feasibility of the active itineraries in real-time.
- viii) Itineraries View which could be map-based, diagram-based, tabular or in textual form.

2.5.4 Information Delivery Technologies

Trip planning services are currently offered through the Internet (web portals), voice portal, and information kiosks located at major transportation terminals. Real-time information provision to en-route travellers is implemented through various communication devices, e.g., SMS or voice mail on the mobile phone and e-mail on the personal computer or PDA of the traveller (see 2.4.4 for further detail).

In many cases, trip planning services are further supported by GIS functionalities. Thus, any trip itineraries specified by the system may be displayed on a digital map of the area under study through a Map Display service. Basic GIS functionalities like panning, zoom-in and zoom-out, are usually provided in order to explore the points of interest near the origin, the destination or any intermediate stop in the trip (Zografos et al, 2009; Zografos et al., 2008).

The voice portal application provides the user with trip planning service without various limitations (e.g. without specifying urban itineraries for the transfers between modes). In a typical service of this type offered through the ENOSIS system (Zografos et al., 2009), the user selects the origin and destination either from a relevant list of locations dictated by the system or by pronouncing the locations himself (voice recognition system). In addition the user selects the date and time of departure of the user, and the system returns the alternative interurban itineraries for his/her journey. The user is

prompted to select one of the alternatives, which in turn is forwarded to a co-operating travel agent for processing the user's request.

2.5.5 Directions for Future Development

Real-time alerting to the traveller regarding any disruption of his/ her trip is a feature envisaged by most of the journey planners. Moreover, international door-to-door trip planning constitutes a major challenge at research level. An EC funded research project called WISETRIP aims at the development of such an innovative trip planning concept, based on the integration of existing urban and national journey planners (WISETRIP, 2008). The expected outcome of WISETRIP is the development of an international traveller information system that provides personalized door-to-door trip planning services and real-time travel information and alerts throughout the entire trip lifecycle. The prototype of the system developed within the project aims to cover several European Counties (Finland, UK, Greece, Italy) and China (see www.wisetripen.org).

This chapter has provided an overview of the main goals, design options, models, technologies and standards underlying the implementation and operation of Multi-modal Travel and Traffic Information Services in their different concepts and forms, offering a background description of the general context of development and operation for the many examples of concrete TTIS implementations provided in the remainder of this book.

CHAPTER 3

Experiences and applications in Europe: the urban level

3.1 Introduction

Most European cities and metropolitan areas are increasingly tackling the problem of unsustainable levels of traffic congestion by adopting an integrated approach, which aims at providing efficient responses to mobility demand and at improving the supply of collective transport services, in addition to encouraging the use of environmentally friendly vehicles and methods. The objective of this chapter is to showcase infomobility in practice by highlighting innovation and good practice across a variety of urban and metropolitan locations in Europe. The following chapter highlights experience at the regional and extra-urban level.

The appropriate use of information, the vital commodity of the 21st century Intelligent Transport System, is illustrated by applications of strategic traffic and mobility management systems (Aalborg, Rome, Florence, Berlin, Cagliari); real-time information for travellers (Cambridge); optimum public transport information (Naples, Vienna), Bus Rapid Transit (Quito); and the flexible transport Agency (Europe).

3.2 Infomobility and traffic management in Aalborg

K. Markworth, G. Friis

3.2.1 Introduction

The traffic on roads in the cities of Europe grows year on year with related problems such as congestion, noise and pollution. Investments only in more roads cannot solve these

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challenges. An additional but not alternative solution is Intelligent Transport Systems (ITS) to enable the traffic to work smarter. In Aalborg the different ITS systems are collected in the Strategic Traffic Management (STM) System, which along with the different ITS systems will be described in further detail in this section. However, ITS systems are often complicated and expensive to develop and maintain and a single organization in a medium sized city often has insufficient know-how to steer and develop such a project. By co-operation the organizations can handle the challenges much better and take over co-ordination, steering and control during the entire project.

ITS is at the core of intelligent structures and of vehicles, infomobility devices and systems and contributes to the intelligent management of mobility processes. Thanks to a tradition of co-operation between authorities in Denmark the authorities have developed remarkable experience and results in the field of ITS. This section describes some examples of co-operation concerning ITS in Denmark which have been implemented or planned at local, regional and national level, as well as the comprehensive STM-system of Aalborg.

Aalborg is the third biggest municipality in Denmark with 193,000 inhabitants and hence the city is the capital of North Denmark. The municipality has an area of 1,144 km². The city of Aalborg is located where the distance over the Limfjord is shortest and hence Aalborg is a north-south transport corridor (see Figure 3.1).



Figure 3.1: The location of Aalborg and the Limfjord

3.2.2 Co-operation at local level

The Municipality of Aalborg has been involved in developing several ITS projects since 1992 under the EU DRIVE, THERMIE, VIKING and CIVITAS programmes. The projects

have been developed in co-operation with the Police, The Danish Road Directorate, North Jutland County and North Jutland Public Transport Authority. It has resulted in the following ITS projects:

- Tunnel Management. Via the Tunnel Management System it is possible to control and supervise the traffic passing through the tunnel. It is possible to close individual lanes and if necessary to guide the traffic through the opposite tunnel tube. In 2005 an Automatic Incident Detection system (AID) was installed. The system can automatically detect slow or stationary vehicles, alert the police and turn on the camera which has detected the incident at the police control centre.
- Queue Warning on the fjord crossing motorway with variable message signs lowering the speed limit as the faster moving vehicles are approaching the queue. The queue warning system covers a stretch of four kilometers south of the tunnel and five kilometers north of the tunnel. The system establishes a speed inlet that lowers the speed limit with 20 km/h for every sign, so the faster moving vehicles are slowing down when approaching the queue. The queue warning system was implemented in 1996.
- Parking guidance shows via VMS the number of free parking spaces in the city. The parking guidance system was installed in 1996 and guides the road users to the nearest parking facility. The system was introduced in order to reduce the traffic circulating for a parking lot. The information is also available from the internet, on the Aalborg Traffic information web site, where a forecasting system is also available. The forecasting system makes it possible to determine whether there is free parking space at the present time, based on the situation at the specific weekday over the last ten weeks. The project was established as part of the JUPITER project under the THERMIE programme.
- Traffic signal control and monitoring. The Municipality controls 110 intersections with traffic signals. Most of the traffic signals are to some degree traffic actuated; only 12 are time controlled. The traffic signals are monitored through software delivered by the supplier of the traffic signals. With the help of software it is possible to monitor the signals, count the traffic on loops, handle errors, use bus priority, etc.
- The Aalborg Traffic information website was elaborated in 1999 and was established with funding from the VIKING programme (Figure 3.2). The website provides information regarding current road works, available parking spaces in the city, the traffic situation on the major routes, real-time passenger information and webcam pictures from the crossing of the Limfjord and the major inlets to the motorway near the Limfjord. *Quo Vadis* Variable Message Signs which showed dynamic route information and would help distribute the traffic between the bridge and the tunnel have now been removed from the roads, but the information is still available, now from Aalborg Trafikinfo. It gives, among other things, information about delays for the fjord crossing traffic.

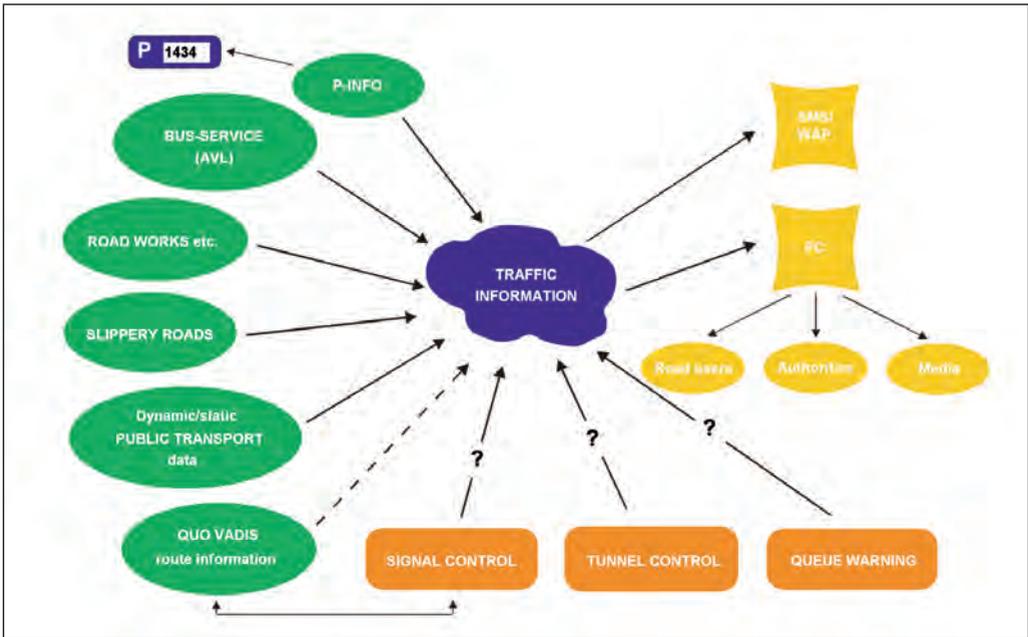


Figure 3.2: Relationship between the different ITS systems and information available on the Trafik-info webpage. The integrated system is the Strategic Traffic Management System of Aalborg

3.2.3 Co-operation at regional level

At the regional level there has been co-operation between the Municipality of Aalborg and the Public Transport Authority in North Jutland on developing several new measures in Aalborg. The projects have been parts of the VIVALDI project in the EU CIVITAS Programme which was a 4 year project ending in January 2006.

The VIVALDI project has resulted in several sub-projects:

- An ITS platform called 'Pubtrans' for steering and operating a compact bus terminal.
- Bus Computers in every bus (248 buses equipped at January 2007).
- RTPi – Real-time passenger information at terminals and on super bus stops (46 signs in operation at January 2007).
- TIC – Travel Information Centre at the compact bus terminal.
- Bus Priority of main signalized intersections (51 intersections equipped by January 2007).

All the systems mentioned above are based on open standards which have the advantages that all IT companies can be involved in the development. It encourages a market mechanism and hence the cheapest and best available technology. The technologies behind the ITS system are illustrated in Figure 3.4.

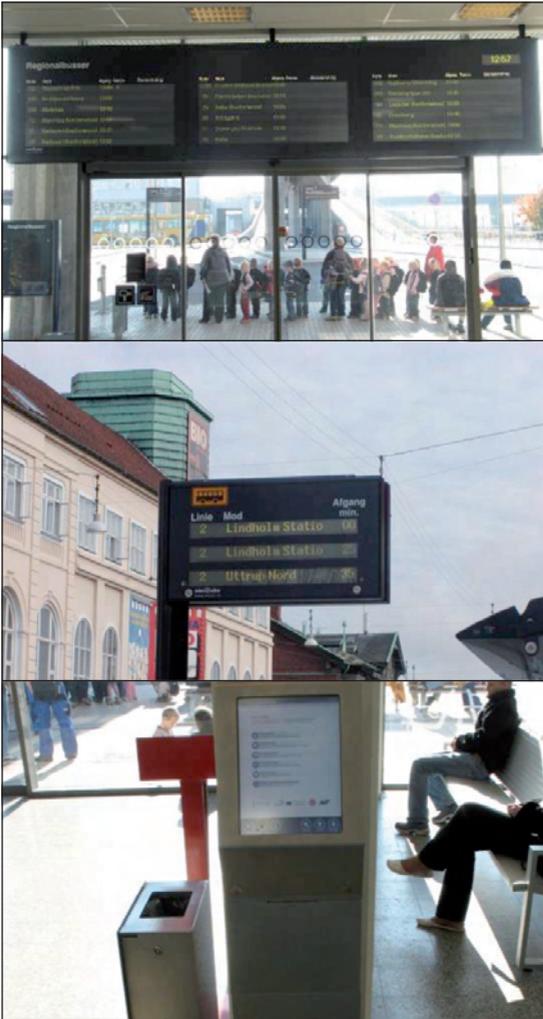


Figure 3.3: Signs with RTPI and the Travel Information Centre

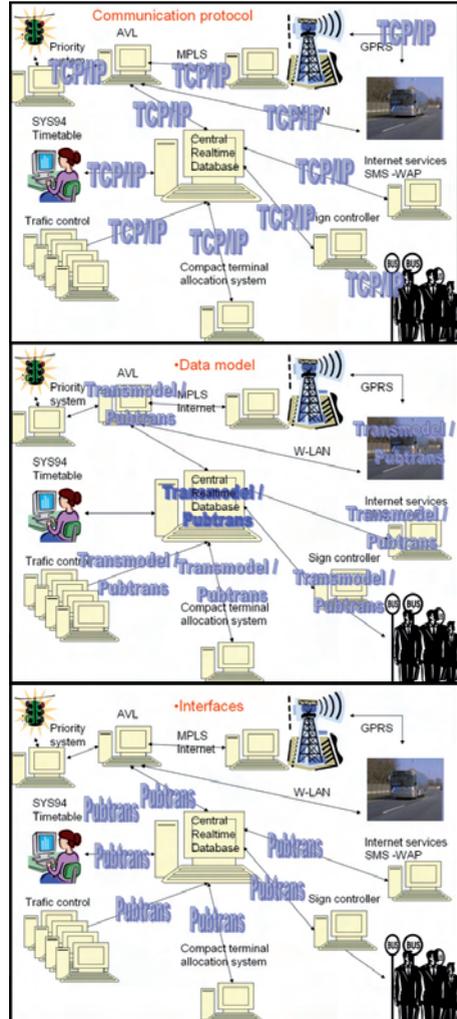


Figure 3.4: The ITS for RTPI and Bus Priority

The first part of Figure 3.4 shows the communication protocol which is used in the system. The second part shows that Transmodel is used as data model for the physical location of the hardware in the system. The last part shows that the interfaces are defined in Pubtrans.

Lessons learned

During these projects a great experience concerning ITS has been build up in the organizations and the most important lessons learned is that open architecture in the

models is a good solution if there is sufficient know how in the organization. It is also important to have a tight steering during the whole time span of the projects. The latter is only possible when there is enough expertise in the organization. Due to these demands co-operation between authorities is a good idea since it can provide sufficient knowledge building and sharing in project organization.

3.2.4 Co-operation at national level

At the national level in Denmark there are two specific projects which are remarkable concerning ITS and co-operation. These are the Journey Planner and a new Travel Card for Public Transport (smart card ticketing).

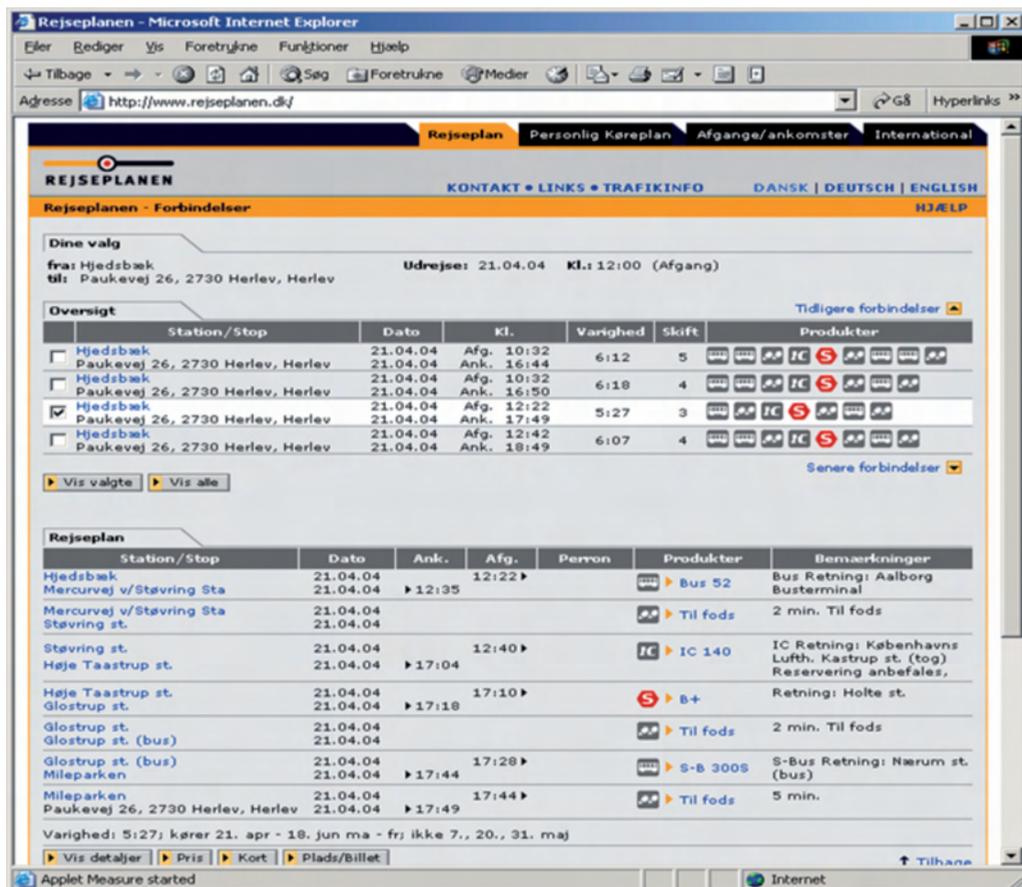


Figure 3.5: The Journey Planner webpage in use

The Journey Planner

The Danish nationwide Journey Planner has been in use for several years and it is under continuous development because new services are introduced. The Danish National

Railway and the Public Transport Authorities in Denmark have responsibility for the development and it has resulted in:

- Improved access to public/multi-modal transport by giving easy access to information.
- Information available 24 hours a day.
- Possibility to find the shortest/best trip between two (or three) points.
- Combination of different routes and means of transportation.
- 'Add on' services as for example walking planner and sights.

The Journey Planner has been a great success. In the beginning of 2006 there were 145,000 users on an average day and the peak was 204,000 journey advices in one day. In January 2006 with heavy winter weather more than 4,440,000 journey advices were delivered. The Journey Planner is now the most used website from authorities in Denmark. The high level of information has also resulted in more passengers using public transport. Surveys show that people are using more public transport than before, among other factors because of easy access to information. Furthermore there has been large savings in Public Transport information services and an improved image of public transport.

The Travel Card

The Travel Card will be one common system for all public transport in Denmark. It is under development by The Danish National Railway and all regional Public Transport

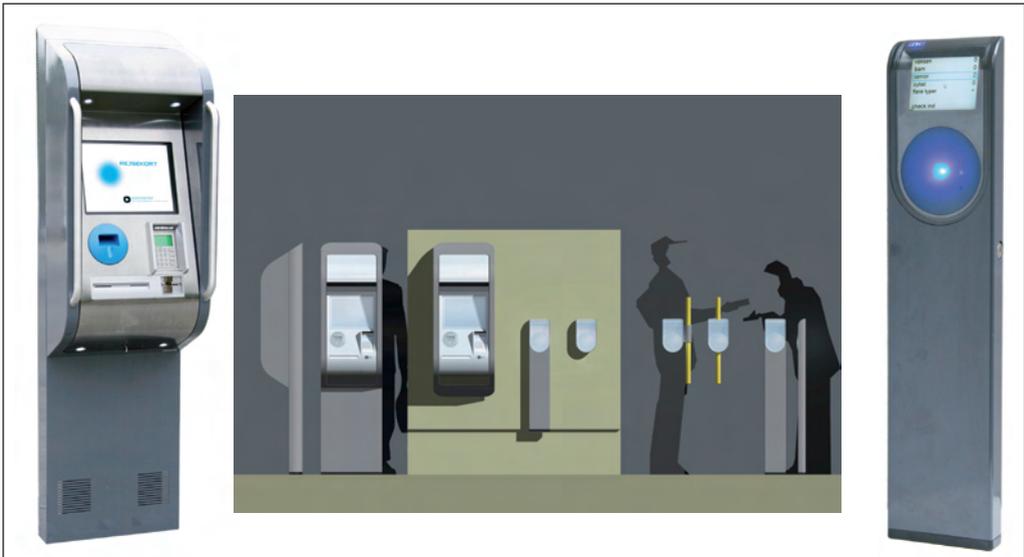


Figure 3.6: The Travel Card System and two designs of the terminals (Source: Travel Card A/S)

Authorities. By implementing the Travel Card there will only be a single fare system for buses, coaches and trains no matter which Public Transport Authority is responsible for the transport.

The Travel Card consists of a smart card which will be a contact free chip card. The users just have to let the smart card pass next to a smart card reader installed at all platforms or at entrances of the public transport vehicles (Figure 3.6). It will be simple to use and the customers do not have to know the fare system. Furthermore, people do not have to worry about the price for a trip because the system will always calculate the price and more journeys result in discounts. The payment will be automatically either pre-paid with automatic load or post paid.

The contract for developing and running the system was signed in June 2005. The Travel Card was implemented in a pilot area in 2007 and throughout entire Sealand (inclusive of Copenhagen) in 2008. In 2009 it was implemented in parts of Jutland with gradual rollout in the remaining parts of Denmark in 2009-2010. It is a large project, hence the price for purchasing the system is above €100 million with approximately the same for operation for a period of 12 years.

3.2.5 Summary

ITS projects are often hard to co-ordinate and steer for one single organization due to lack of knowledge in-house. In Denmark co-operation between authorities has resulted in organizations with sufficient know-how in developing and implementing ITS projects at each of local, regional and national level. In public transport the results are especially remarkable with co-operation between all stakeholders; the Journey Planner and Travel Card products are the most ambitious and challenging.

3.3 The Infomobility system in Rome

E. Cera, M. Cagnoli, C. Di Majo, A. Falvo, M. Ieradi

3.3.1 Introduction

The role of Information to end users is nowadays assuming a primary role for the modern Mobility Agencies. It is on the subject of the so called “Infomobility” that during the past few years an important evolution has taken place regarding both technologies and communication channels used to distribute information.

It is recognised at European level that in a range between 5% and 24% of the cases people do not take advantage of public transport just because of a lack of adequate information (source UITP 2003). This shows that information systems cover an extremely important role in the whole management of mobility, which grows in parallel with the increasing demand for mobility. Accurate information can provide:

- A higher travel comfort, in fact it allows users to take travel decisions (e.g. change of mode) especially in conditions of traffic congestion.
- Better and more efficient use of the transport network;
- Better safety conditions in general, as a result of the improved level of service of the road network and of the driving conditions.

During the past decades the information systems linked to mobility have undergone an important evolution. We have passed from the static road signals to the variable message signs that provided dynamic information although not differentiated or personalised by road user during the trip. To-day a large range of telecommunication and information technologies is available; the way of providing information on mobility for the Agencies has significantly increased. Internet, Personal Traveller Assistant, Navigators, mobile phones; all these systems allow an individual and personalised access to the information and a quicker and easier distribution of information.

3.3.2 The Rome Mobility Centre

ATAC, the Rome Mobility Agency, is the owner and manager of the Mobility Control Centre of the Capital. The Mobility Centre was implemented in 1998 in time for the new Millennium (2000). Besides the traditional management and supervision of the “private mobility”, such as the City Limited Traffic Zones (LTZ), traffic lights, parking and the relevant information, the Mobility Centre has also to manage, integrate and develop all the public transport related services.

Rome’s commitment towards the enforcement of the Access Control Systems is in place and is being developed with the support of the ITS features (electronic gates and back-office service system); new integrated Infomobility services are being developed, in order to increase the access to mobility information to a larger audience, making it available also through the mobile devices of common use.

The components of the Rome Mobility Centre may be summarised as:

Systems:

- Traffic signals
- Video Surveillance Cameras – traffic
- AVM - Automatic Vehicle Monitoring
- Electronic gates (Limited Traffic Zones)
- Traffic flows measurement stations
- VMS - Variable Message Signs
- UTT - Urban Travel Times
- Electronic bus stop
- Electronic payment system

Data Analysis:

- SIM (Mobility Information System)
- SIT (Geographic Information System)

Infomobility:

- Infopoint - Journey planner (Figure 3.8)
- Moby - On-board bus information
- Trovalinea - bus/tram maps and timetables
- Parking and bus ticket via SMS
- Atac mobile (real-time information on mobility on mobile phones)

Latest developments:

- Automatic detection of overtaking offence
- Monitoring of red light violation (PhotoR&V)
- Bus Lanes Monitoring
- Speed Monitoring System (SICVe)



Figure 3.7: Predicted bus arrival times at electronic bus stop



Figure 3.8: Infopoint journey planner

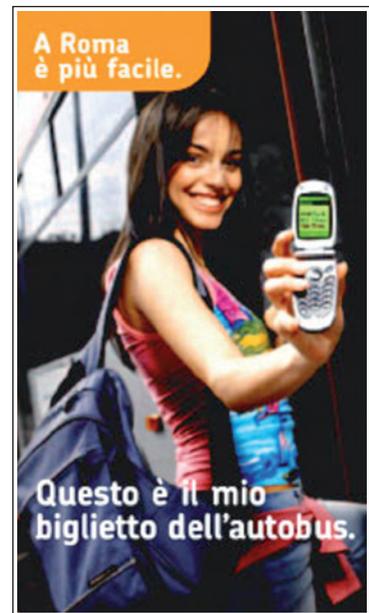


Figure 3.9: Advertisement about ATAC electronic ticket

3.3.3 The ATAC experience

The first approach to Infomobility through ITS in Rome was made by ATAC with the “Infopoint” at the end of 1998. The service, available on the ATAC website (<http://www.>

atac.roma.it) and through the ATAC Call Centre, and from 2007 on mobile phones and palmtop (<http://mobile.atac.roma.it>), is a journey planner based on private or public transport information, or on a combination of them. Translated in 5 languages it also provides information about tourist routes made by public transport, cycle paths in Rome and the map of the most important places of interest in the city, such as tourist attractions, services, shopping centre etc.

With the new Millennium (2000) ATAC started the installation of 52 Variable Message Signs (VMS) spread on the main roads of the city, providing information about traffic, accidents, demonstrations and many other suggestions or educational messages. From 2006 an experiment started with the VMS, which now also provide information about travel times on 4 main roads, giving information on the road Levels of Service in real-time; this service is going to be extended to the whole city.

Another system to provide information to public transport users, called MOBY was implemented in 2003. LCD screens, connected via GPRS to a central system, have been placed on 300 buses (Figure 3.10). This provides passengers with the following information during their travel: next stop, diversions of route, instructions for authenticators and also about leisure, social-cultural events and the activities in Rome, tourist information, places of interest, updated news, etc.; news from the world; advertising messages, horoscope etc. RomaRadio, the official ATAC radio, provides this kind of information in the whole Underground network, extending Infomobility “under” the city.



Figure 3.10: MOBY service LCD screens providing real-time travel information to passengers



Figure 3.11: Public transport information via VMS

From August 2005, the Automatic Vehicle Monitoring system (AVM) was implemented allowing ATAC to monitor its vehicles; from May 2006 the AVM also allowed to provide information about estimated arrival time to public transport users through 300 electronic displays placed at the bus stop. Electronic bus stop displays are also used by ATAC to inform travellers about events and road works.

In 2004 a survey was carried out by ATAC on mobility behaviour on commuters in Rome, focusing both on the use of public transport and of the private means of transport to reach the working place. According to the analysis carried out the share of people making multi-modal choices (private car + public transport) has increased compared to the share of “mono-modal” choices (e.g. only private car). In order to comply with the new emerging demand of multi modality, ATAC has improved and modified its communication strategy towards city dwellers, first of all by including information on public transport through the VMS spread in the capital, so far dedicated only to car users.

In this framework ATAC has recently launched (May 2007) a new information service, called “Atac mobile” which is accessible through mobile devices and combines the provision of private and public mobility information into one product which is always and everywhere available (Figure 3.12). It is possible to browse Atac mobile information through mobile phone and PDA.



Figure 3.12: ATAC Mobile infomobility services on users mobile phone

The list of “Atac mobile” services includes:

- **News** - real-time news on traffic, status of road works, demonstrations, access restriction policies in place.
- **Traffic Bulletin** - allows to check a list showing the traffic conditions by zone.
- **Urban Travel Times** - on 5 main roads of the Capital
- **Journey Planner** - provides the best routing calculation taking advantage of public transport, an interactive map is also provided.
- **Videocameras** - 45 videocameras can be chosen to display the situation of traffic (images are updated each 5 seconds).
- **Useful Information** - information and advice on services useful for the citizens, and the relevant contact details and phone numbers.
- **Bus arrivals** - The information on arrival times per bus line at each bus stop. The information is generated by the AVM system.

3.3.4 Conclusion

Infomobility in Rome is mainly based on the ITS systems of ATAC Mobility Centre. “Atac mobile” is the latest and one of the most important services developed within the Mobility Centre. The powerful innovation of Atac mobile is the simplicity of the service, its user-friendliness, its being open to new technical features and new contents, its interoperability and its being of support to sustainable mobility. The characteristics may be summarised as follows:

- **Simple:** Atac Mobile has been developed with low investment; it has optimised the performance of existing technologies and taken advantage of previous investments;
- **User-friendly:** Atac mobile is accessible through any GPRS/UMTS mobile phones; everyone can choose their trip (with public transport or Car) in real-time through a user friendly interface.
- **Open:** standard protocols (Xhtml, XML; etc.) have been used to develop the software; the platform is based on web servers that can be interfaced to all the different ITS systems;
- **Interoperable:** Atac mobile is predisposed to collect any kind of information and services from different mobility stakeholders.
- **Sustainable:** Atac mobile provides added value information especially for public transport users; being everywhere aware of the bus arrival time and of the optimal route by public transport will incline citizens to have more sustainable behaviour by leaving the car and increasing the use of public transport.

What can be done in the future with Atac mobile? The service can be customised: the frequent users can be identified through an ID and provided with specific information

linked to their habits (value added service), for example on the home-work shifts, the preferred bus lines, information of the neighbourhood etc. The service can be integrated with electronic payment systems (e.g. parking, bus ticket, etc.). Because of the new Location Based Services (LBS), Atac mobile can provide either targeted information (e.g. the closest bus stop, parking meters, metro stations, etc.) or targeted services (e.g. best routing calculation starting from the GPS localisation). The contents and information provided by Atac mobile can be enhanced, in order to include for example, relevant information about Bike Sharing and Car Sharing (reservation and payment, new applications such as the bicycle best routing calculation etc.).

3.4 A Reference Infomobility ITS Model for Florence Metropolitan Area

G. Ambrosino, S. Gini, A. Ferrari, N. di Volo, F. Pescini

3.4.1 Introduction

In today's urban mobility scenarios, many constraints – ranging from urban structures and environmental issues to regulations, costs of road infrastructure and community budget limits – have lead Local Authorities to look for ICT tools and systems as a fast and efficient response to a number of complex and compelling issues. These include traffic congestion and the consequent pollution, poor accessibility and low usage of Public Transport, as well as lack of sustainable mobility schemes providing an attractive alternative to the use of private car. Very often, especially in Southern European countries, there is an evident lack of co-ordination among the various public and private entities – car traffic, Public Transport services, freight and goods transport, emergency services, etc. – that with different aims, roles and responsibilities share the same road infrastructure and generate negative impacts whose cumulative effect is very visible in terms of environmental quality and city life sustainability.

If this is generally an issue for most European city centres, it is certainly a more relevant problem for historic cities like Florence, the capital city of Toscana Region, in central Italy, where the morphology of the territory and the structure of the urban network are tightly integrated in a very complex, extended and precious historic centre with the presence of many cultural heritages and tourism assets.

For these reasons, the need for appropriate measures to address traffic and mobility problems in the city centre, and especially in the historic part of it, has always been a main concern for the Local Administration, which has become a major issue in recent years as a result of the growth of mobility demand and traffic volumes. This has led to the deployment of several ICT tools and systems dedicated to Mobility and Transport management which have begun to strongly influence the decisions and choices of Local Authorities (Municipality, Public Transport Companies, Province Council, etc.) with

the background aim of meeting fundamental city objectives including: *affecting mobility demand, increasing quality of environment, increasing the overall accessibility of the city and strengthening social cohesion.*

This section aims to provide a proposal of a Reference Model for the Infomobility system to be adopted in the Florence Metropolitan Area, and of the process that should lead, in the course of the next few years, to the implementation of the designed infrastructure. The Florence Infomobility system is designed as an evolving project for completion over the next years integrating several Information and Communications Technologies (ICT) and Intelligent Transportation Systems (ITS). The model takes into account a possible evolution path towards the provision of several infomobility services and the analysis and evaluation of network traffic impacts.

The remainder of this section is organised as follows: Section 3.4.2 outlines the overall context of development of the Florence Metropolitan Area ITS system, providing background information about the main needs and objectives of Local Administrations, as they appear from the public documents (Mobility Plan, etc.) that the ITS infrastructure should meet. Section 3.4.3 illustrates the main strategic options which the Florence Local Administration could adopt in order to introduce the new ITS system. Section 3.4.4 discusses a preliminary proposal/design of the Reference ITS Model for the Florence Metropolitan Area, while section 3.4.5 outlines the principles and main elements of the accompanying Master Plan of ITS Services, which the Florence Administration could take into account to develop and adopt for a successful and effective deployment of the target ITS infrastructure and services.

3.4.2 The Florence Metropolitan Area context

Characteristics of the territory and mobility patterns

The city of Florence lies on the east side of a wide amphitheatre generated by the Arno river and its different effluents, surrounded by hills degrading up to the edge of the built-up area that during the centuries have represented a significant natural barrier. Being a world cultural capital, Florence is characterised by a very old cultural and economical history, with a huge tourist flow during the entire year.

The morphological characteristics of the city area have always strongly influenced the use of the territory in the urban centre and in the outskirts. Most of the main administrative offices, schools, business and leisure facilities are still located in the historical centre, inside the beltway (the “Viali di Circonvallazione”) surrounding the inner and historical part of the centre, together with a high concentration of monuments and museums. Despite the rising number of people working in this area, the number of inhabitants is still decreasing, as in many European major city centres, with people moving to the residential areas located in the suburbs.

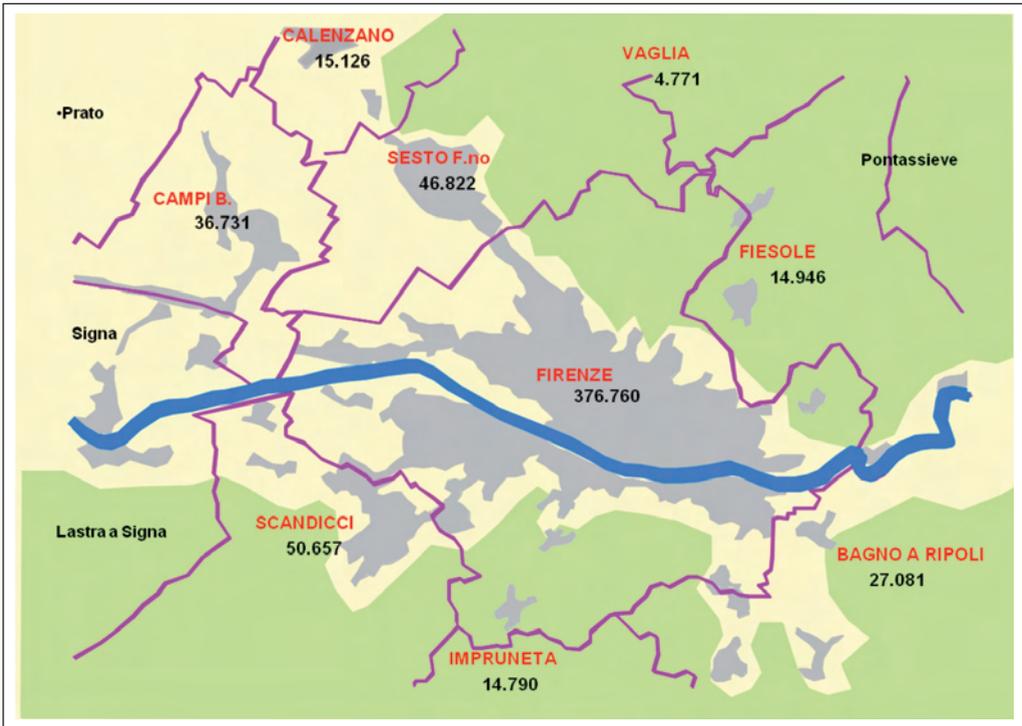


Figure 3.13: The city of Florence and the surrounding towns defining the Florence Metropolitan Area

At present, Florence is in the centre of a vast Metropolitan Area (Figure 3.13), which comprises Florence itself and some of the municipalities in its suburbs (Impruneta, Bagno a Ripoli, Fiesole, Vaglia, Sesto Fiorentino, Calenzano, Campi Bisenzio, Scandicci) and constitutes a homogeneous large city. The overall population of Florence Metropolitan Area about is around 600.000 inhabitants, with an average density of about 1.130 inhab./ km², which is quite high compared to the average density of the whole Province of Florence (about 150 inhab./km²).

In recent decades there has been a strong phenomenon (as in many European Cities) of migration from Florence to the surrounding municipalities, thus increasing the mobility relations inside the area. This has further increased the demand of private mobility, leading to the current modal split which is still much in favour of private means: 60% cars, 30% Public Transport and 10% other modes (bikes and pedestrians).

Mobility planning and management measures and supporting ITS

In order to meet the increasing mobility demand and reduce the adverse effects of traffic on the city, Florence Local Authorities have undergone a number of measures addressing both land and mobility planning as well as the proper management of mobility. The city

strategies and policies related to this are defined in the Urban Transport and Mobility Plan (P.G.T.U.) which was adopted few years ago.

The main planned measures, partly realized and still being developed, include:

- the cessation of development of new residential settlements within the municipality territory except in two areas located in the south-west side of the city;
- the increase of Public Transport services efficiency and effectiveness by realization of several measures including: a set of dedicated Public Transport corridors along selected arterials of the primary road network, increase of the number of tangential Public Transport lines connecting directly the suburbs, etc.;
- the realization of a tramway network, linking the most important zones of the metropolitan area and the historical centre.
- the improvement of the metropolitan railway network through the reuse of local and regional rail tracks and local rail stations;
- the completion of a network of bike corridors;
- the deployment of the Automated Access Control system at the main gates of the Limited Traffic Zone (inner part of the historical centre);
- the definition of a new parking policy and fare scheme, with the aim of discouraging the use of private cars (especially commuters and occasional parking) and stimulating the split towards public transport;
- the creation of interchange nodes and a set of parking places for intermodality, located at intermediate distance between the more peripheral lots and the inner centre;
- the introduction of innovative “sustainable mobility” services including Demand Responsive Transport (DRT) and car-sharing schemes.

ICT solutions and ITS, together with clean vehicle technologies, are obviously a main instrument to implement the above measures. Over the last years, Florence has realized a number of technological measures and implementations:

- traffic light co-ordination for more than 110 junctions, with co-ordination for bus priority;
- traffic flow data collection with more than 70 on-street sensors;
- Access Control system for the city centre, with 15 automated gates;
- Public Transport fleet monitoring and control with more than 380 equipped buses, currently being extended to other companies and to the tram system acting on the same road network;
- integrated parking management system, with five co-ordinated areas and car sharing parking lots (7 areas);
- on-street dynamic information system including:
 - road traffic conditions (20 VMS panels)
 - user information at bus stops (bus arrival times; more than 30 bus stops, currently being extended)

- parking information (place availability) and guidance panels
- integrated payment system based on contact and contact less card;
- environmental pollution monitoring system with 10 data collection stations;
- Flexible Transport Dispatch Centre providing information and booking for Demand Responsive services operating in the sub-urban area;
- car sharing system (linked to a national Service Centre; more than 20 shared cars in the area, currently being increased);
- web portals with Public Transport information and services including a “Mobility Manager” portal;
- Wide Area Network based on optic fibre and shortly on Wi-max
- clean vehicles fleet with 144 CNG buses, 26 electric buses and 2 CNG depots.

Such systems represent the backbone of technological infrastructure for a possible Florence Integrated Mobility System, provided their development is brought forward in the framework of a co-ordinated strategic plan.

Among these, a special role is assigned to the new tramway system as the main axis of a renewed Public Transport offer and of the new mobility system. This is based on three co-ordinated tram lines, as shown in Figure 3.14. The operation of the first tram line 1 will be at the beginning of 2010, together with a reorganisation of the Public Transport network, will mark a major innovation in the overall city mobility system, and will significantly add to the process of reorganising Florence urban mobility towards clean and sustainable city objectives. The other two tram lines have been decided from the technological point of view and are under a final decision for the final patterns routes. In Figure 3.14 the three tram line are indicated as planned at the beginning.

In order to properly achieve this, the implementation of a technological support framework is needed in order to be able to enhance the day by day transport network management and control, allowing:

- the monitoring and control of all Public Transport services, with a special focus on a general “priority and security” policy for the tramway lines in the overall road network;
- the increase of bus network role as “feeder” to the new tramway lines;
- the extension of traffic light co-ordination and provision of traffic light priority to the tramway lines and to the other main Public Transport lines (“Public Transport Busway System”);
- the extension of the network of traffic data collection detectors;
- the enhancement of user information at the main bus and tramway stops;
- the implementation of an integrated tariff and payment system among tramway, bus, parking and local/regional train services;
- the strengthening of the Park & Ride system, with the integration of the different involved facilities (parking sites) and with a dedicated set of VMS panels;

- the provision of dynamic, updated pre-trip and on-trip information for both private and public users;
- the co-ordination of intermediate transport services (DRT schemes) in the different urban quarters including the inner centre.

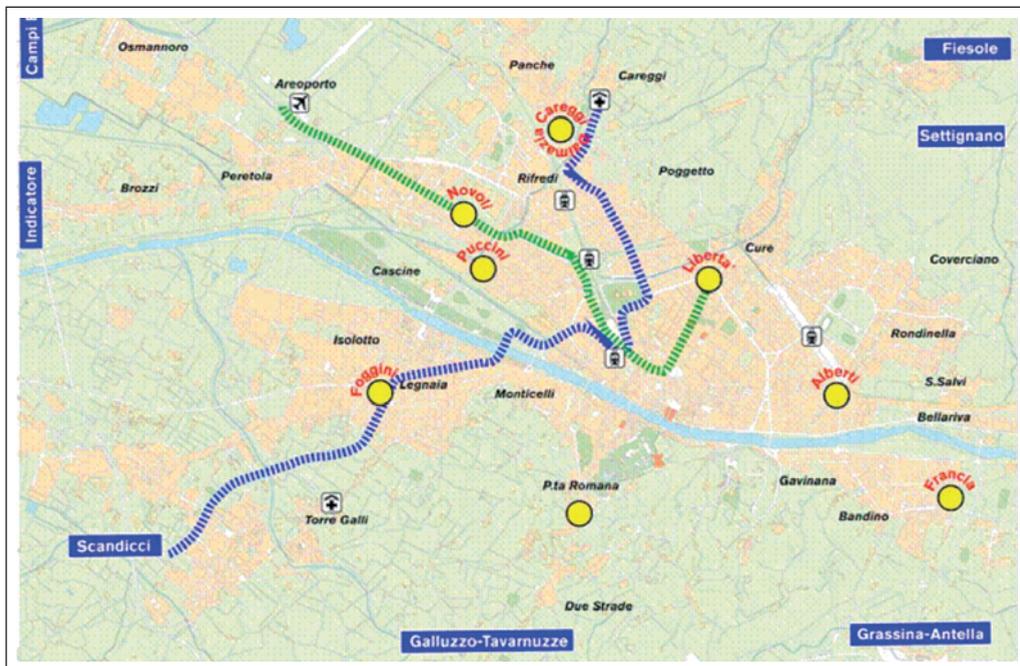


Figure 3.14: The Tramway line network of the City of Florence at the first design

3.4.3 ITS strategy for Florence Metropolitan Area

In the general context introduced in the previous section, and starting from the existing infrastructure and technological level, the definition and design of an ITS Reference Architecture for the Florence Metropolitan Area is a main need for a co-ordinated and sustainable development of the Florence mobility system.

In order to achieve this, the Florence Administration should also define the general process which should lead to the identification of the Reference Architecture that suits best the objectives of the Administration. At the foundation of this investigation process, it has adopted a few key principles and objectives to be taken into account in the definition of the Reference Architecture, including:

- strengthening of the overall mobility and transport planning capability, both at urban and metropolitan level, with the introduction of specific tools (modelling, methodologies, simulation, statistical analysis, integrated data bases, etc.) to support the

technicians of the Local Administrations in the definition and control of the different measures/interventions (traffic circulation rules, Urban Traffic Act, Urban Parking Areas Act, Mobility Plan, etc.);

- extending and/or building services and light infrastructure in order to monitor the different processes in the mobility network and acting both at the level of daily management and of planning. This involves the realization of a set of ICT infrastructures and ITS services such as, for instance: wide communication backbone, Wi-Fi hot spots, user information provision (before the journey, on the road, at home, at work, etc.), traffic light co-ordination, bus/tram traffic light priority management, parking areas integration and guidance, access control and possible road/congestion pricing policy applications, integrated payment system and tariff, Public Transport fleet monitoring, flexible transport services, tourist buses park management, urban logistics, etc.;
- developing the necessary system integration level among the different ITS services implemented on three complementary aspects: technological, operational and organisational, in order to enable an efficient information integration (collection, processing and distribution), an efficient co-ordination of the different mobility components and a real networking among the different actors within the mobility network.

Following such general criteria, an *analysis of the main needs of mobility governance in the Florence Metropolitan Area should be conducted* in order to design an effective ITS reference framework on the basis of the objectives provided by the political level and indicated in the Urban Mobility Plan (priority to Public Transport, reduction of the pollution level and traffic congestion, increase of social cohesion, etc.).

At the entry of this process is the design and realization of an Integrated Mobility Management and Control System for Florence Metropolitan Area based on ITS systems and services and on advanced tools for the analysis and evaluation the different network impacts. This involves the implementation of an ICT platform for mobility governance targeted at both the management of different network processes and the provision of infomobility services, as well as to the networking and co-ordination of the different stakeholders involved in Florence mobility services and processes.

This platform/system should be a kernel component of a Centre providing specific services to the citizens and travellers of Florence Metropolitan Area, including:

- pre- and on-trip information, traffic conditions, accessibility of the different transport services (Public Transport service information, parking areas conditions, tram/buses feeder conditions, etc.);
- guidance and control of tourist flows (private cars, buses, etc.) and of the service cars in the city;
- value added services to be operated by different service providers;
- realization of specific intermediate transport services for tourists, citizens with disabilities, elderly and /or disadvantaged citizens groups.

Initially, such a base platform / Service Centre should be operated in a “zero revenues” scenario, but it should bear from the beginning some potential for future recovery of costs. In other words, it should show potential for providing, in a second step, targeted services with high added value and economic return (e.g. by the introduction of pricing policies implemented through the automated access control system in specific urban areas).

3.4.4 A possible ITS Infomobility model for the Florence Metropolitan Area

On the basis of the existing and planned technologies and systems for the Florence Metropolitan Area a preliminary Infomobility Reference Model can be defined, based on a two-level hierarchical architecture:

- 1) *Tactical Level*, represented by the single systems which control the specific processes they are managing. The most relevant systems from the point of view of the primary needs of Florence Metropolitan Area include:
 - traffic data acquisition on the road network
 - traffic light co-ordination (UTC)
 - public transport fleet management (AVM)
 - access control system (ACS)
 - parking areas management and roadside guidance information (PMS)
 - road users and travellers information through variable road signs (VMS)
 - environmental monitoring (EPM)

Such systems operate on a common traffic and transport network with their own control and implementation strategies (and related devices);

- 2) *Strategic Co-ordination Level*, including services related to the analysis and interpretation of network conditions, the identification of traffic situations, the dynamic identification of the different management objectives and criteria to be proposed or imposed to the systems belonging to the Tactical Level.

In this model, the lower level elements *1)* operate as data providers (the updated knowledge about traffic levels on the network, for example, is provided by the UTC system; pollution levels by the EPM system; etc.) and as responsible units for the implementation of specific actions/policies (e.g. traffic light plans by UTC, information messages by VMS, management of parking areas by PMS, etc.).

The higher level *2)* operates as a functional component providing network state identification and the evaluation of the overall mobility strategies and /or actions. In this respect, level *2)* represents the higher knowledge level and the provision of traffic information to different operators and agencies.

These two architectural levels provide the backbone for the Florence ITS Reference Architecture and are open to several possible future extensions, including:

- a) towards the “field”, introducing components/devices implemented on the network (sensors, traffic lights, VMS panels, pollution data collection stations, user information panels at bus stops, communication network, etc.) and/or on the vehicles/buses (on-board systems, ticket validators, on-board information, etc.)
- b) towards the upper level (planning level) for the planning and evaluation of network mobility scenarios, with the capability to couple the operational/management environment devoted to day-by-day mobility governance with the longer-term analysis and planning of new measures and network management policies in response to the main transport issues and options identified.

This Reference scheme should therefore allow three main objectives to be achieved:

1. the integration between different technological schemes operating on the network in order to dynamically define and develop integrated and complex monitoring strategies (integrated *monitoring and management level*);
2. the integration and co-ordination of mobility monitoring strategies allowing the generation, integration and distribution of information to road and transport service users, with the aim of influencing mobility demand (*integration between control and information*);
3. interaction between the network monitoring and operational management phase and the transport policy planning and adaptation (*integration between monitoring/management and planning phases*) providing a fundamental element for a “Mobility Observatory” able to follow the changes and modifications of mobility demand and offer over time and support strategic planning activities accordingly.

Figure 3.15 provides a general outline of the ITS Infomobility Reference Architecture suggested for the Florence Metropolitan Area.

In the Reference Architecture a few key “axes” can be identified (from the functional and operational standpoint), which are more relevant for the Florence Metropolitan Area, and whose related components are already implemented and operational on the Florence network:

- **Traffic Management**, involving the Co-ordination Centre with several sub-systems such as: traffic data collection, traffic light co-ordination, pollution monitoring, traffic light bus priority;
- **Traffic Information management**, involving sub-systems such as: Variable Message Signs, parking management and guidance, bus stops information, web portals for users (and operators) information services;
- **Public Transport management**, including the fleet monitoring and control centre, the travel dispatch centre (for Demand Responsive Transport services), user information at bus stops, integrated payment system.

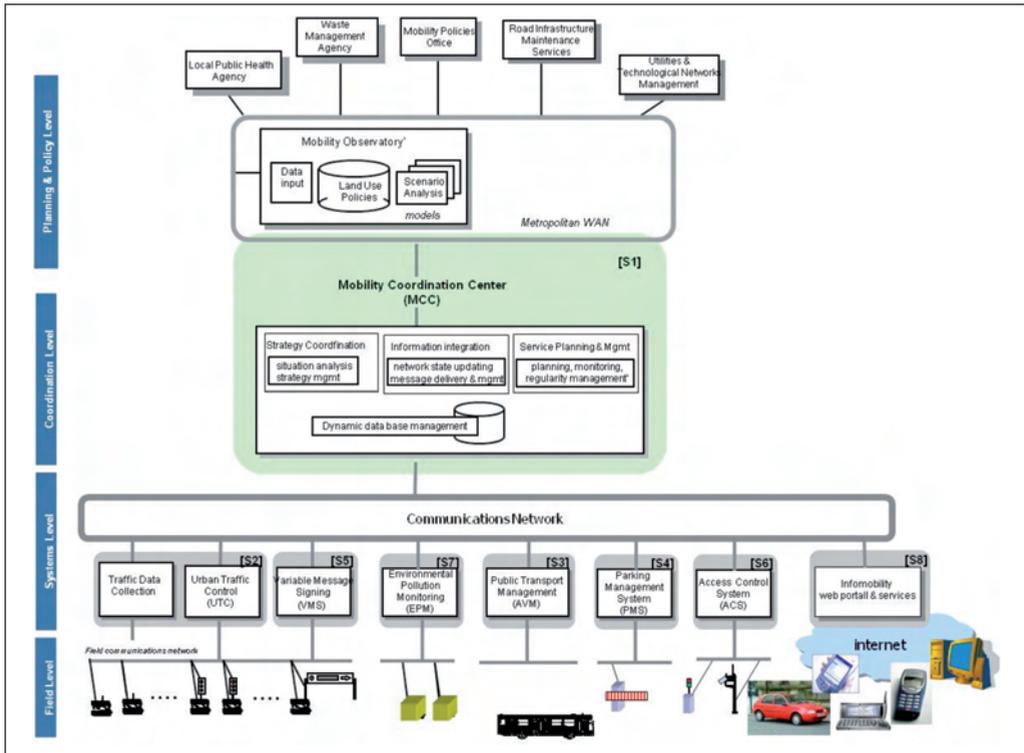


Figure 3.15: Preliminary Architecture of the Florence Metropolitan Area ITS infrastructure

This scheme represents the baseline technological infrastructure for the implementation of further targeted value added ITS services of interest for Florence Metropolitan Area such as: the Agency for Flexible Services (e.g. DRT, car sharing, car pooling, bike sharing, etc.) discussed further in 3.11, the Traffic and Travel Information service centre, the Limited Traffic Zone access control and pricing schemes, city logistics services (e.g. e-Logistics Agency), the tourist bus service centre (e.g. parking and guidance services), the P+R service management and the modal integration services for road transport and the tramway system, etc.

During the detailed design and planning of the reference ITS model special attention should be paid to the different institutional stakeholders operating in the Metropolitan Area of Florence (City Councils, Transport Companies, Provinces, Highway Companies, Florence parking services, Taxi Drivers Associations, etc.) who are responsible, in different ways, for mobility related issues and services. These actors will be involved (directly or as users/operators) in the development of the overall co-ordinated mobility management system and consequently their different levels of contribution to and integration with the proposed architecture will have to be identified and carefully investigated.

3.4.5 A Master Plan for ITS services in the Florence Metropolitan Area

Based on the Reference Architecture outlined in the previous section, the implementation of the actual ITS architecture for the Florence Metropolitan Area should be driven and controlled by a Master Plan for ITS Services which defines the best options for technology and service deployment in the area.

The definition of the Master Plan is a fundamental step to ensure the co-ordinated implementation and successful exploitation of the selected ITS solutions and services follow the strategic objectives set by the city Administration. Particularly, the Master Plan for the Florence Metropolitan Area should be defined taking into account the main city policies which, as previously discussed, include:

- a drastic reduction of the congestion levels of the network and the related environmental impacts;
- the improvement of the overall quality of Public Transport services offered to citizens and travellers in the Metropolitan Area;
- the optimization of Public Transport operation by monitoring, controlling and co-ordinating the bus fleet with the new tramway lines;
- the monitoring of the traffic network situations and the implementation of the appropriate response measures;
- the provision of infomobility services for individual road users and Public Transport travellers;
- the creation of a Permanent Mobility Observatory for the entire chain of “land-use-transport-energy consumption-transport emissions”, able to support city and mobility planners to optimise mid and long-term measures and actions.

The Master Plan will have to provide a strategic reference plan for the development of technologies and the application of the most suitable ITS services for the Metropolitan Area of Florence. The present situation in terms of mobility demand and technologies, as well as the role of the Institutions and of the Agencies operating in the Mobility and Transport field, should represent the starting elements for the definition of the plan.

A further evaluation related to the priorities of the different measures and implementations will have to be undertaken together with the definition of the technological and technical framework. Time, financing and institutional restrictions will also have to be taken into account at the same stage.

Overall, the activities for the definition of the Master Plan of ITS Services for the Metropolitan Area should include the following main steps and activities:

1. Existing context:

- definition and analysis of the characteristics and needs of the Metropolitan Area;
- available technologies and resources;
- present projects and planned interventions;

- involved stakeholders/actors(Organisations, Agencies, users categories);
 - preliminary analysis of macro requirements of the different stakeholders and actors in the area;
2. Reference Architectural Model:
 - Operational and logic scheme;
 - Information flows and enabling technologies;
 - Institutional and operational constraints and requirements;
 3. Identification and preliminary planning of the applications and ITS services for the Florence area:
 - requirements;
 - functionalities;
 - operational schemes;
 - involved technologies;
 - costs;
 4. Identification of communications needs among the different technological services;
 5. Integration issues:
 - Technological and operational features;
 - Competence domains and roles of the individual stakeholders and actors;
 - Interaction with external systems;
 - Organizational levels and operational complexity;
 6. Definition of implementation priorities and of a preliminary financial plan for the identified ITS applications;
 7. Definition of a technical/operational structure for the governance of mobility and transport in the Metropolitan Area.

During the following phase, the operational steps for the realization and management of the process concerning the identified ITS applications shall be defined. In order to carry on the planning activities as defined above, a Technical Committee should be created. The Committee should operate with different Institutions and Agencies working in the Florence Metropolitan Area in the field of Mobility, Transport and Environment, having as a main goal a proper co-ordination of the definition and implementation of the Master Plan with respect the two tightly interlinked levels previously introduced:

- Planning level, for the definition of the application of urban technologies most suitable for the Florence Metropolitan Area (Master Plan);
- Operational level, for the implementation and management of the overall process related to the applications and ITS systems identified in the planning phase.

3.5 Real-Time Information in Cambridgeshire

E. Evans

3.5.1 Introduction

Cambridge is a historic city in the East of England, United Kingdom. It is the major centre of the predominantly rural county of Cambridgeshire. Cambridge city is linked to a ring of market towns by strategic roads serving motorists, public transport and freight. Cambridge has a population of 110,000 so it is a medium-sized city but the population is increasing.

Cambridgeshire is one of the major growth areas in the UK. Major urban growth is planned at the fringe of Cambridge and in a completely new town called Northstowe on the northwest of Cambridge. Adjacent to Cambridgeshire are the city of Peterborough on the northwest, and the County of Bedfordshire on the southwest. There is considerable traffic across the boundaries of these authorities with bus operators providing services linking the cities and towns.

Real-time information has become an important complementary service running in conjunction with other timetable information sources such as telephone, web site and text messaging. Cambridgeshire County Council (www.cambridgeshire.gov.uk) recognised the potential benefits of using this technology and began the installation of various applications of the technology. Real-time information technology has been applied to providing parking availability information in the city and to public bus services. This technology will be applied to a major transport infrastructure scheme, the Cambridgeshire Guided Busway. Cambridgeshire's experience demonstrated the effective approach of working in partnership with key stakeholders, with well-defined roles and responsibilities for each partner. Experience has highlighted the essential factors for success that include consideration of long-term development needs and sound financial arrangement.

Why real-time information?

The city of Cambridge is made up of narrow streets crowded with historic buildings, and intertwined with modern construction accommodating the rapidly expanding population. In order to ensure the city traffic runs smoothly, good infrastructure and signage have been developed over recent years. Real-time information for public transport, vehicle access and off-street parking is an important initiative in Cambridgeshire.

3.5.2 Applications in Cambridge

Real-time bus information

A major application of real-time information technology is for bus services. In the UK, the provision of bus and train services is de-regulated. This means that the Government does not have jurisdiction over local transport operators and has to work together with them in order to introduce new information systems.

As a transport authority, Cambridgeshire County Council is keen to promote bus usage. Introducing a real-time bus information system will help to achieve this objective. Neighbouring transport authorities in Bedfordshire and Peterborough also have the same intention. All three authorities decided to pool resources and formed a partnership to do this.

Passenger experience - For the passengers, the technology can provide information on bus arrival time. This information can improve passenger confidence in bus service performance and can encourage them to use bus services more. This is particularly appropriate in areas with rural services or inter-urban services like Cambridgeshire. Real-time bus information can be given to bus users in various ways such as through display signs, enquiry over the telephone and information through the internet.

Real-time passenger information signs are displayed at bus stops or in public areas such as shopping centres, business parks and hospitals (Figure 3.16). The sign will show the service timetable until about 20 minutes before the bus arrives, depending on the frequency of the service, and then the countdown will start. When it reaches 1 minute before arrival, the sign will display “due”. The signs are also able to indicate wheelchair access and can be activated by key fob to give voice information to the visually impaired passengers.



Figure 3.16: Bus stop displays

Driver and depot experience - For the bus drivers, real-time bus information gives them better communication with the depot. There is display equipment in the vehicle to show them how well they adhere to the timetable and for them to receive text messages. Previously drivers can only communicate with the depot or another driver using mobile phone.

For the bus operators real-time bus information technology provides fleet management information, which is a powerful tool for them to manage service performance, in particular in urban areas such as Cambridge City, where buses are prone to delay caused by busy traffic. The fleet management product in the system includes automatic vehicle location GPS tracking and performance analysis. At the depot there is facility for voice communication to all or selected vehicles within an operators' fleet. Performance analysis records are integrated with existing vehicle scheduling software of the operators. There are other potential add-ons that are not installed yet but the system chosen is able to provide, for example real-time occupancy information and on-bus CCTV.

Real-time information technology is applied to intelligent traffic management. Currently bus priority uses the loop and tag system, which gives all buses priority at traffic lights. With real-time information, bus priority will be given with respect to real-time need. For example, the traffic light will only change to give bus priority when the bus is detected to be in service and running late.

Scope and process of Implementation - The implementation of the system was commissioned in June 2005. The terms of contract will run for 10 years. For the entire area of the three authorities there will be 400 vehicles equipped, 200 signs on display, 6 depots involved and operation at a minimum of 40 road junctions. However, the capacity of the system is more than double the scale being implemented.

The transport authorities are investing in the capital to provide the infrastructure. This includes all the signs, equipment on vehicles and in depots. Operators provide staff to operate the system and make a financial contribution to maintain the system.

For the implementation process, it began with silent testing. This gave operators an opportunity to become familiar with the system and make alterations to the timetables if necessary. It also gave the technical team opportunities to address any system problems. The pilot testing was with Cambridge University where students and staff helped to test the signs on-site and the development of information access through the University intranet. In 2006, real-time information was introduced in phases to cover major city services and a major corridor service.

Parking Space Availability

In Cambridge real-time information technology is also applied to provide information on parking space availability for drivers approaching the city. Although this does not require very advanced technology, the information given is useful to visitors in helping them choose the route to their destination. Display signs are placed on radial roads into the city, giving information to visitors on the number of parking spaces available at each city centre car park. When drivers see that the car park they are heading for is full or approaching capacity, they have advanced warning and a choice of going to other car parks or using the Park & Ride service.

In Cambridge there are 5 P&R sites on the outskirts of the city, which are situated along all the main arterial routes into the city centre. Bus services then connect the P&R sites to the city centre, and run at 10 minute frequencies. Information of the parking availability of city centre car parks is linked to display signs on the approach roads to the P&R sites. These signs will display a message to advise drivers to use the P&R service as an alternative way of travel or when the city centre car parks are full.

This type of real-time information helps to ease the busy traffic situation in Cambridge by reducing the need for drivers to drive through or drive round the city centre looking for a parking space.

Cambridgeshire Guided Busway

Real-time bus information will be applied to the Cambridgeshire Guided Busway, a major new transport infrastructure scheme being implemented by Cambridgeshire County Council. The Council was a partner in the Interreg III C *TransUrban* project, which examined the development and operation of urban transit systems in small to medium-sized cities (www.transurban.org).

The Cambridgeshire Guided Busway is a bus-based rapid transit system linking the city of Cambridge with Northstowe new town and the historic market towns of St Ives and Huntingdon. The busway will open in 2010. Design and service standards are being specified to incorporate real-time bus information. Operators intending to use the guided busway will be required to meet the specified vehicle standard, including provision of compatible real-time bus information equipment.

This requirement is considered necessary for the Guided Busway to match its image of a rapid transit service. Passengers will be able to access real-time information in many different ways. In addition to the display signs at bus stops, there can be signs at major journey destinations such as shopping centres, schools and hospitals. Information can be accessed via the internet, telephones and even passengers' own homes. Some sections of the service are run on road. Intelligent bus priority using real-time bus information technologies will be one of the measures to ensure high performance.

3.5.3 The Partnership Approach

The Partnership Board

Three transport authorities, Cambridgeshire County Council, Bedfordshire County Council and Peterborough City Council, recognized that it was to their mutual benefit to utilise pooled resources and to ensure compatibility for cross-boundary services. From our experience, working with stakeholders in a partnership is the best way to implement a system like this. The Partnership was formed and led by Cambridgeshire County Council (Figure 3.17). The Partnership Board consists of members from:

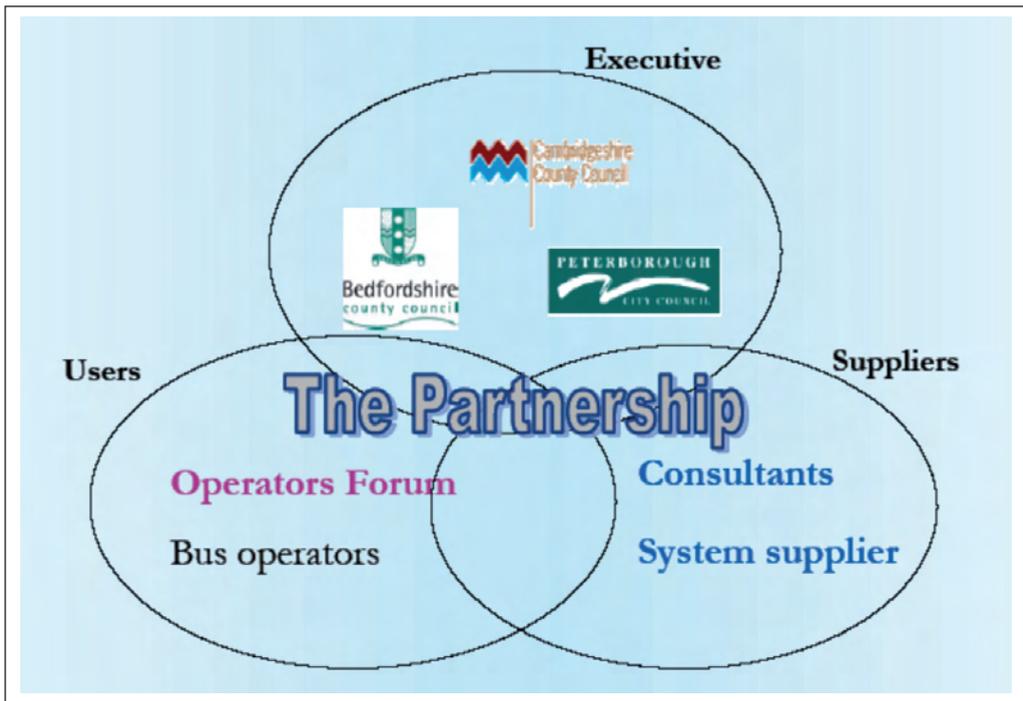


Figure 3.17: The partnership approach in Cambridgeshire

The Executive - The transport authorities who have the responsibility of promoting public transport use. Currently the members are Cambridgeshire County Council, Bedfordshire County Council and Peterborough City Council. System specification takes into consideration other adjacent authorities and Cambridgeshire's system is capable of joining up with others in future, if necessary.

Users / Operators' Forum - The users in the installation of real-time bus information are the bus operators, representatives of the bus industry. As there are a number of bus operators providing services in the area, an Operators' Forum was formed to give them a co-ordinated opportunity to discuss objectives, aspirations and implementation issues.

Suppliers - This group of members includes the suppliers of the technical system and the experts giving technical advice to the local authorities.

Role of the Partnership

Well defined role of the different groups of members - The role of the Executive is to direct the project of installing the real-time bus information system and to ensure the project stays in focus. The project takes years to implement fully, as there are hundreds of vehicles to equip and hundreds of signs to display. The technology is developing all

the time and is capable of delivering vast functionality. Therefore it is a key role of the Executive to agree clear objectives and scope of the project with the Partnership, and to keep the project within budget and timescale.

The role of the **Users** is to develop, implement and operate the system. The equipment will be installed on their vehicles and in their depots. It is their role to specify the requirement of a system that meets their needs and that they can operate efficiently.

The role of the **Suppliers** is to supply the equipment and technical advice. The system supplier in the Cambridge case is ACIS. They provide the system including the equipment and installation. It is their role to liaise with the users to specify any technical needs such as bus timetable information, routing information and existing bus scheduling software. Consultancy experts Atkins provide advice to assist the Executive with decisions on technical matters. Both the system supplier and the consultants have regular meetings with other members of the partnership to discuss and resolve issues.

Co-ordinated role of the Partnership - The Partnership with all stakeholders working together ensures that all needs are discussed and decisions are made in agreement.

Technical specification for the system came from the agreed objectives. The Executive ensured this was communicated with the suppliers. In agreeing the system specification, long-term development was considered at the beginning of the project. For example, the real-time bus information system can be integrated with Cambridge University to provide data for traffic modelling, and with the National Health Service to plan hospital appointments. It can also be integrated with display units in residential homes to give tailored information to residents such as real-time travel news.

The Partnership agreed the timescale for implementation. It is only when all members of the Partnership are involved that the timescale can be realistic and will be adhered to.

3.5.4 Conclusion

- We find that the partnership approach worked. All partners have their role to play. With other authorities involved, we were able to specialize in various functions of the system. For example, Peterborough City piloted the features for disabled passengers while Bedfordshire focused on the performance reporting aspect. Involving users at all stages also ensured their commitment.
- It is vital to have clear and agreed objectives. The technology is so advanced that it can probably offer any function you want but can be over-complicated. It is only when we have clear agreed objectives that we can formulate a meaningful and workable brief to the supplier to give us something we need and within our budget.
- It is also vital to have an agreement of long term financial arrangement in place to operate as well as to maintain the system. If necessary, there should be contractual agreement specifying the arrangement. In the Cambridgeshire case, the transport

authorities provided funding for all capital investment. The Partnership agreed a mechanism to fund the maintenance of the system. All operators participating in the real-time bus information system agreed to pay an annual membership fee. The amount depends on the size of the operators' fleet in each depot. Cambridgeshire County Council, as lead partner, administers the fees.

- In choosing the most appropriate system, future long - term development must be considered. Cambridge has a high proportion of professionals who are more receptive to technology. Therefore any new information system should be hi-tech enough to reach them.
- For a large scale implementation project like this, a well-planned phasing programme is necessary. Cambridge started with a pilot route for silent testing, followed by a cluster of routes in the city centre and then corridor routes. Evaluation is planned at key stages to inform and improve the implementation programme.

3.6 Infomobility and traffic management in the Berlin area¹

P. Aicher, M. Beer, J. Glauche, U. Reiter, F. Logi

3.6.1 Introduction

Economic success and economic progress today depend heavily on mobility. Equally, individual mobility is seen as a synonym for freedom and quality of life. According to a Eurostat survey, 215 million passenger cars are currently registered in Europe, as opposed to about 64 million in 1970. Of these 215 million cars, 190 million are registered in the EU-15 states (1970: approx. 62.5 million). Since 1970, passenger traffic in all modes of transport in Western Europe has increased by a factor of 2.5.

In 2003, West Europeans travelled a total of 5,000 billion kilometres in cars, buses and trains – the lion's share going to road transport. Eighty-four per cent of all kilometres travelled in the EU-15 states were travelled by car, whereas the railways could claim only 6.3 per cent and buses 9 per cent. In the industrialised countries of the Organisation for Economic Cooperation and Development (OECD), three per cent of the gross domestic product or 810 billion US \$ have to be spent annually on coping with the consequences of overly trafficked roads. This over-use of transport routes also sometimes results in substantial damage to roads and bridges. Moreover, heavy traffic is associated with accident risk and is an immense strain on the environment.

The consequences of this transport phenomenon are well known: at peak travel times, both passenger traffic and the rapidly increasing freight traffic are beset by congestion.

98 1 Based on an article published in *Strassenverkehrstechnik*, September 2006.



Figure 3.18: A challenge for Berlin's administration: preserving mobility



Figure 3.19: Constantly updated traffic information in Berlin

In particular in agglomerations like Berlin, the fragility of the balance between flowing and stopping traffic can be witnessed every day. One reason is that more and more commuters crowd the streets during rush hours (Figure 3.18). In the coming years, every morning more than 100,000 vehicles are going to flow into the city and back into the surrounding towns in Brandenburg in the evening. Berlin's A100 city motorway is one of the most frequented sections of the entire German motorway network. On average, the Funkturm interchange is used by 200,000 vehicles per day.

Moreover, the traffic infrastructure in East and West Berlin followed different development paths while the city was still divided. In West Berlin, the traffic planners structured the street network by a number of ring roads; in the eastern part of the city, in contrast, the main arteries are aligned radially towards the centre. This means that still today, people travelling from East to West Berlin generally have to traverse the city centre. The government district forms the hub for the various traffic flows, which causes additional problems during state visits or demonstrations.

Berlin's street network comprises roughly 5,500 kilometres, nearly 1,600 of which belong to the main arteries network. Every year, the city's traffic administration issues more than 30,000 official orders and instructions that significantly limit traffic in public road space. For instance, traffic flow is impacted by more than 300 roadwork sites at any time. The obstructions range from a simple construction site trailer blocking a single lane, to the partial or complete closure of entire streets being dug up for work on gas or water pipes, power or telecommunication lines (not to mention the four or five film crews per day, whose work often blocks entire streets). This situation is compounded by more than 3,000 annual events taking place in Berlin's streets, including the Berlin Marathon, major events around the "Great Star" in the Tiergarten park, the weekly skater parade through the city and innumerable district street festivals.

Berlin's traffic control centre registers half a dozen or more police-escorted trips of government officials per day, and at least one state visit convoy per week. Added to this there are about 3,000 registered demonstrations per year, mostly between early spring and early fall. Small demonstrations at notorious traffic hotspots can have as much impact on traffic as large demonstrations on the "Strasse des 17. Juni", the main artery through the Tiergarten.

For all these reasons, detailed and up-to-the-minute traffic information is indispensable for road users in Berlin. In recent years, the 3 million inhabitant metropolis has commissioned the development and operation of a comprehensive mobility management centre for the collection, analysis, and provision of urban mobility information. Since summer 2000, the VMZ traffic management centre in Berlin informs road users in advance on expected traffic obstructions, jams and street closures. During scheduled events or roadworks, Berlin residents and visitors can thus look for alternative routes around the area concerned or simply use the public transport system (Figure 3.19).

3.6.2 The VMZ traffic management centre as a new information platform

The Berlin VMZ is a computer-supported traffic management system that makes traffic information on public transport and private traffic available (Figure 3.20). The objective of the VMZ is to provide residents and visitors with up-to-date traffic information. The system is operated by Siemens on behalf of the German state of Berlin, in a public-private partnership. The traffic data for the VMZ are provided for example by its own detection network of solar-powered sensors, which collect data on traffic density, speed and the ratio of private vehicles to trucks and send the information per radio link to the VMZ. The VMZ also processes so-called Floating Car Data provided by taxi companies and public transit authorities: taxis and buses on the road regularly transmit their current position and speed, allowing conclusions as to the current traffic flow.

The VMZ Berlin, as provider of traffic information via Internet, information panels and various other media, and the VKRZ Berlin, as the integrated traffic control centre, rely on a common traffic data pool. The VKRZ provides loop detector measurement data, which are then supplemented by the VMZ with traffic data gathered by more than 200 Traffic Eye Universal (TEU) detectors. Then the MONET prognosis model, developed jointly by Siemens and PTV, generates a description of the current traffic situation and a prognosis for the main street network. Moreover, the VMZ passes messages on traffic disturbances (e.g. roadworks) on to the VKRZ. The VMZ is also responsible for controlling the information panels. However, the operators at the VKRZ can monitor the text messages currently displayed on the panels by the VMZ and, depending on priorities, manually insert pre-defined or freely programmable text messages.

The current traffic situation can be viewed on the internet at "www.vmpzberlin.de". The motorists on the street are informed by means of dynamic message panels

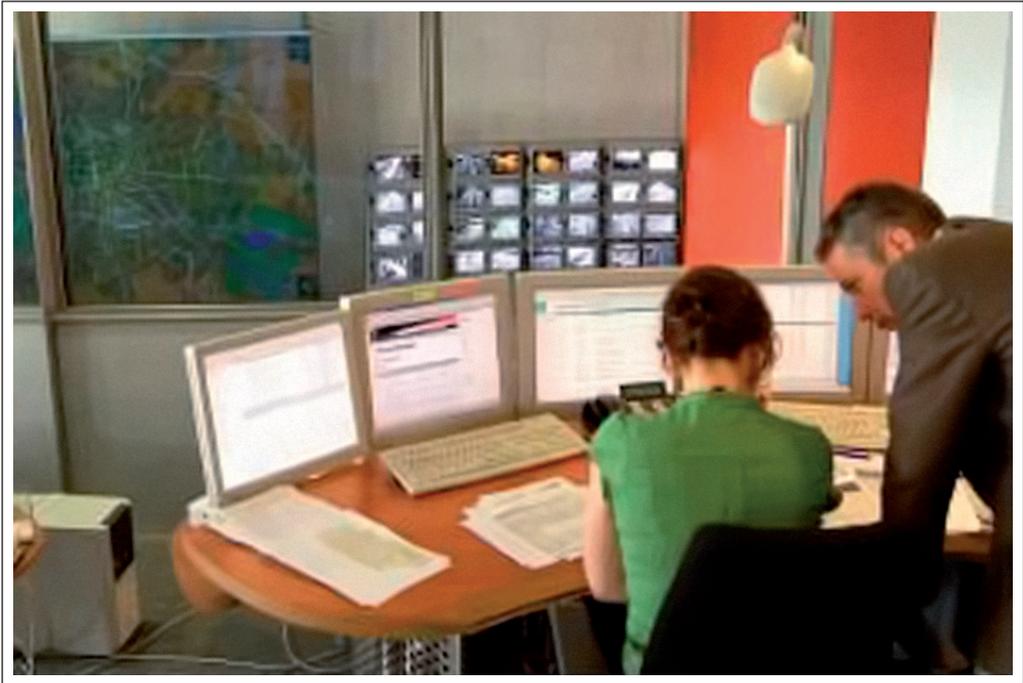


Figure 3.20: The VMZ traffic management centre in Berlin

displaying information on traffic incidents or events and on options for switching to the public transport network. The data and services are not only offered free of charge on the Internet and the displays, they can also be downloaded directly per SMS and/or WAP-capable mobile phone.

Soccer World Cup – a mega-challenge mastered

Up-to-the-minute traffic information was especially important during the Soccer World Cup because the traffic flows to and from the events in the Olympic stadium and the inner city overlapped widely. This was an immense challenge for Berlin's traffic planners as the goal was not only to be a good host to all soccer fans but also to keep the city and its street network operational over five eventful weeks. Traffic around the Olympic stadium was not the only focal point; the spotlight was also on the many events in the inner city area with more than 500,000 visitors. Important east-west arteries were only partially open to traffic or even not at all.

This is why the Berlin Senate developed in advance wide-area traffic concepts, relying on the extensive experience and data pool of the VMZ. The Senator for Urban Development, Ingeborg Junge-Reyer, praised in particular the campaign "Berlin steigt um" because it met with much acceptance from Berlin residents. They left their cars at home

and chose rapid transit trains, underground, public bus lines and quite often even the bicycle to get to the city centre or to World Cup events. If large numbers of residents had not systematically switched to public transport, Berlin would not have been able to cope with the traffic challenges created by the World Cup. Up to 95 percent of visitors took trains or buses to get to the stadium. This percentage exceeds by far the numbers for other World Cup venues. On match days, the so-called “modal split” - the ratio of different means of transport used for travelling to and from the stadium - reached 90 to 10 for public versus private transport. Shorter intervals between trains for rapid transit and underground as well as the new guarded bicycle parking areas at the main event venues have certainly contributed to this large-scale switch to alternative means of transport. In the inner city, car traffic has declined by a sizeable 5 percent while bicycle traffic has climbed by 25 percent.

During the Soccer World Cup, the temporary “Zentrale Leitstelle Verkehr” co-ordinated and guided the traffic flows, based on the traffic data provided by all transport authorities. The police, the public transport authorities of Berlin, the Berlin fire brigade, the VMZ traffic management centre, FIFA and several departments of the Berlin traffic management office were all involved. In addition, the traffic management departments re-programmed a large number of traffic lights in order to lessen the burden on the city centre. At the same time, the automated traffic count and monitoring systems were expanded on certain inner city arteries. The VMZ and the traffic management office will continue to use the data that are being additionally collected since the World Cup to improve their assessment of the traffic situation.

3.6.3 The new VKRZ at Tempelhof airport

Europe’s largest and most modern traffic control centre, the Berlin VKRZ, is located in the buildings of the former Allied Forces aviation safety facility at Tempelhof airport. It replaces the old centre, which was initially designed for controlling a total of 1,000 traffic light installations and had been in operation for 25 years. Now the new VKRZ controls traffic lights at more than 2,000 intersections and programs the variable message signs on 300 display gantries on national motorways around Berlin. A 20-square-meter rear-projection wall now shows, for the first time ever, a comprehensive picture of the traffic situation on Berlin’s streets, roads and motorways. The urban area is studded with 650 measuring stations that collect information on the prevailing traffic situation on more than 1,500 street kilometres. The traffic situation is clearly visualized, with green denoting flowing traffic, yellow indicating slow-downs and red marking congestions. At the same time, the rear-projection wall displays the location of roadworks and events in the public traffic space. More than 100 video cameras monitor the traffic on the city motorway and in the tunnels, sending the video sequences to 32 monitors. In case of congestion, centre operators can switch the pictures of individual road sections



Figure 3.21: The VKRZ traffic control centre in Berlin

to a separate monitor for checking the speed and the number of vehicles travelling on the various lanes (Figure 3.21).

The centralization of all traffic-relevant information at one location has created the technical environment required for targeted interventions by Berlin's traffic managers to minimize or even prevent traffic disturbances. The operators can switch deviation programs, block or open additional lanes on certain main arteries, as well as modify speed limits on selected road sections. The decision-making procedures are not restricted to individual modes of traffic but serve to derive measures for optimizing processes in the entire traffic and transport system.

The VKRZ is integrated with the state traffic warning service, which provides road users with RDS/TMC messages on constantly updated information on traffic jams, failed traffic signals, roadwork sites or demonstrations. The orders and permits issued by the Berlin traffic management office with regard to roadworks and demonstrations are passed on to the VKRZ where they serve as input for traffic situation prognoses, which in turn are distributed by the traffic warning service in the form of traffic bulletins. Traffic bulletins are generated automatically whenever traffic measurement stations detect values in excess of preset limits (dense traffic or standstill). The corresponding information and warnings

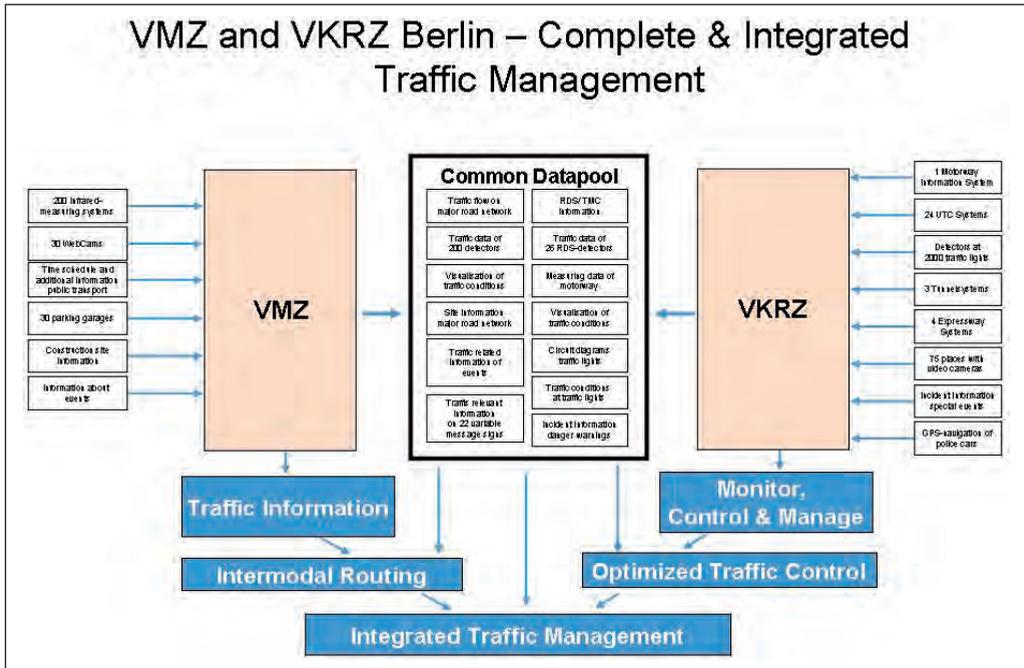


Figure 3.22: Interfaces and interaction between VMZ and VKRZ

are transmitted to the recipients linked up with the traffic warning service, such as all radio and TV networks, providers of telematics services (dashboard navigation systems, mobile navigation systems) as well as newspapers in Berlin and Brandenburg. For nationwide information coverage, the messages are also transmitted to the national traffic warning service from where they are distributed to all other regional traffic services. In co-operation with the other consortium partners, Siemens established the state traffic service's first ever interface for the automated generation of messages on traffic light failures and on disturbances caused by roadwork or congestion (Figure 3.22).

The open software interfaces ensure the centre's expandability and adaptability to new tasks at any time. For instance, the VKRZ system can readily integrate new functionalities regarding air pollution monitoring and response measures. At present, an early traffic warning system is being developed as part of the IQ mobility research project in the framework of the VM2010 research plan of the German Federal Ministry for Education and Research. When pollution values exceed certain limits, this early warning system will propose dynamic control strategies that also take quality indicators into consideration.

Improved traffic flow and reduced environmental pollution

Studies have revealed that, in spite of increasing traffic volumes, the "green sections" on the city's motorways have expanded since the installation of the different traffic regulating

systems. This means that, even during rush hour, speeds around 80 kilometres per hour (the maximum speed on the Berlin city ring) are reached much more often.

The improved traffic flow has also a positive impact on fuel consumption. The comparison between the average consumption during measurement drives on the test section before and after the systems' installation shows a reduction in fuel consumption by 3 percent. For private cars alone (the consumption changes of the measurement vehicle have not been translated to trucks), the reduction in CO₂ emissions between 06:00 and 10:00 and 16:00 to 20:00 on the 8-kilometer test section totals over three tons per day.

The technical concept behind the VKRZ

For monitoring and controlling the 2,000 traffic signal installations, the former central operating computer, which no longer meets modern performance requirements, was replaced by a new traffic control centre called VKRZ Berlin. The new system is based on Sitraffic Concert. The goal was not only to expand control functionality, but also to ensure the seamless integration of existing systems, for instance the existing traffic computers, tunnel controls (process computers of the Sicomp R and Sicomp M series) and traffic regulating systems installed at various times and by different manufacturers, as well as the new OCIT traffic computers. In no more than four weeks, the 22 traffic computers were migrated from the old central operating computer to the new VKRZ traffic control centre and that with only a minimum of downtime for each computer. No changes needed to be made to the existing interfaces with outdoor installations, so that the state of Berlin did not have to shoulder any additional modernization costs. The integration of the Sitraffic P2 traffic engineer workstation system, which the State of Berlin was already using, could be smoothly integrated for the signal program supply of traffic signal installations.

The highlight and most important tool in the command centre is the 20-square-meter multimedia wall, on which Berlin's urban area can be visualized in exact detail. The multimedia wall consists of 25 DLP rear-projection modules with a total of 5120 by 3840 pixels and a display surface of five by four meters. The system plots information on traffic light status, detected traffic jams, roadworks and outdoor events on the displayed digital map. The data are visualized simultaneously on this surface and can be processed by the system to yield condensed traffic information.

The images gathered by Berlin's 100 existing cameras distributed along the city motorways from the Tegel Tunnel in Reinickendorf via the Charlottenburg interchange to the Neukölln interchange are displayed on 32 monitors and at the operator stations in the VKRZ. They offer an excellent overview of the traffic situation on the motorways and on the access and exit ramps. For road users, the work of the VKRZ traffic operators becomes most obvious at those locations where critical traffic situations trigger interventions in the form of entry restrictions by barriers, for example at the Antonienstrasse and Siemensdamm motorway access ramps.

3.6.4 Strategic management and action plans prevent congestion

Whenever certain predefined operational or traffic situations are detected, the strategy management module of SITRAFFIC Concert automatically generates a sequence of actions or recommendations for action. The recommendations support the traffic control operator in selecting the right response to any of a wide range of possible incidents. Dedicated user interfaces provide extensive functionality and standardized output interfaces for controlling and feeding information to secondary systems such as signs, cameras, media, and other subsystems. For this function, the operators in the VKRZ constantly add more action plans to the system archive. The integrated action plan management supervises the individual steps of each strategic control sequence with focus on the problem at hand and the required measures. The function relies on data from all available sources, not only its own system parameters but also all relevant data from the subsystems and detectors. Sophisticated algorithms are used to process, weight and compare the collected values. Whenever certain predefined conditions are fulfilled – for instance a certain “level of service” on a road section, public transport data, car park occupancy levels, events or roadwork projects, certain time criteria, or a combination of various states and situations – the system initiates specific, targeted actions. The interfaces of the central action plan management are generically structured so that traffic analyses, control sequences and action controls can be realized based on the currently available systems without special software adaptations.

The strategic management module (Figure 3.23) can be used for monitoring all activated strategies and their currently executed process steps. Thus the operator can find out at any given moment which process step has been reached in each of the activated strategies. For each process step, the operator is also given information on the actuating conditions and on the subsequent strategy steps. This makes all strategies transparent and traceable for the operator, during the planning as well as during the execution phases. In case of aborted strategies, for example because of actuator failures or lack of switching feedback, the manager executes the control sequence in reverse order based on a so-called terminating action plan. The system offers traffic engineers and operators convenient options for the fast development of simple and complex strategies, the execution of which can then be effectively supervised through graphical representations. In conjunction with the central time-dependent, automatic switching routine, which covers traffic signs, traffic computers and other subsystems, this system allows the easy generation of traffic intervention and action plans for known events and unforeseeable incidents, including efficient execution monitoring.

3.6.5 Conclusion

By creating Europe’s largest and most modern traffic control centre, Berlin has created the technical conditions for centrally monitoring and managing traffic in the entire

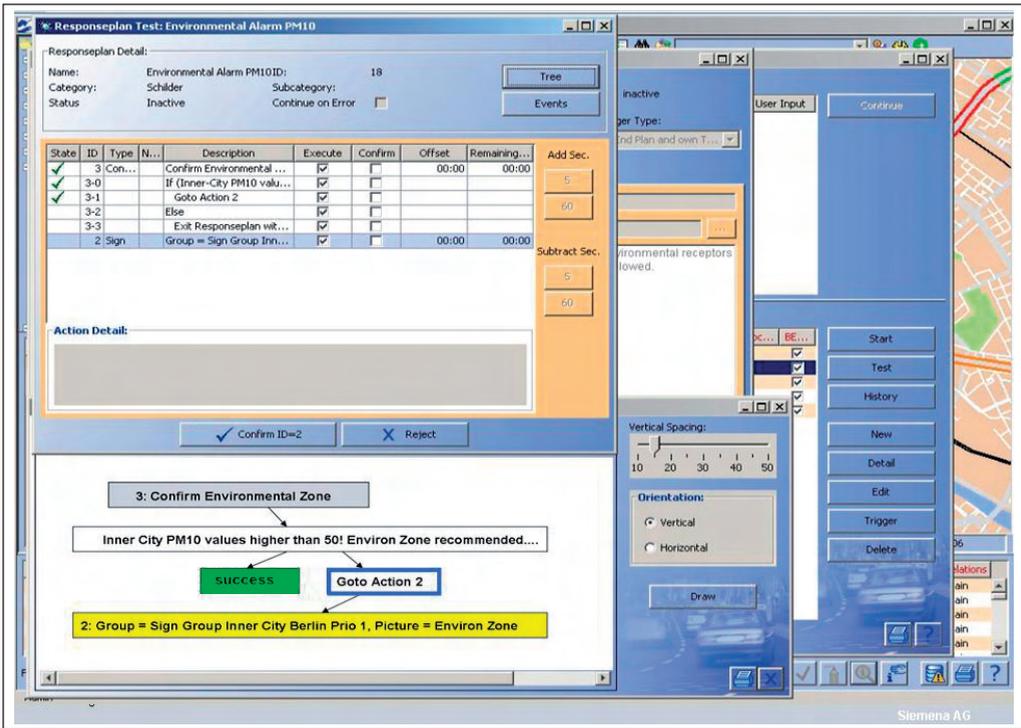


Figure 3.23: Control of the freely programmable information panels of the Berlin VMZ

metropolitan area. For the new central control facility, all traffic management, control and regulation systems established in the Berlin region within the past 25 years have been networked and installed on a common hard- and software platform. For the first time ever, a comprehensive picture of the traffic situation on the motorways, roads and streets in greater Berlin can now be provided. The analysis of current and collated traffic data is the basis for mobility management that is able to deal effectively with traffic disturbances and congestion.

3.7 Real-Time public transport information in Naples: evaluation of an AVM system

A. Paribelli, V. Teti

3.7.1 Introduction

ANM, the Public Transport Company of Napoli Metropolitan Area, have been operating an advanced fleet monitoring system for real-time service control and reporting for more than ten years. The overall reference architecture of the system implemented at 107

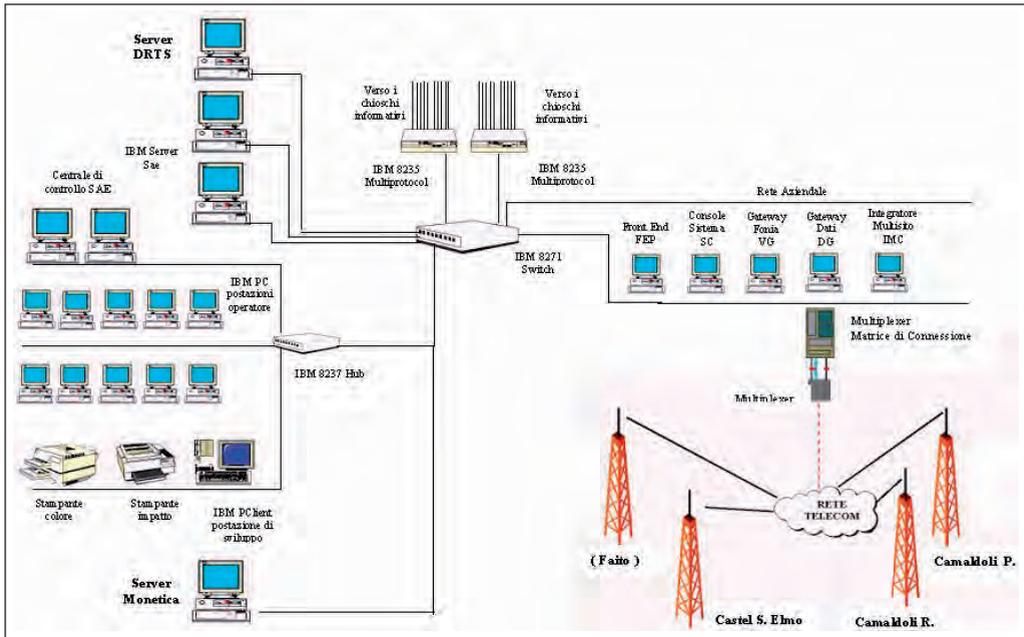


Figure 3.24: Overall architecture of the AVM system operated by ANM in Naples

ANM is shown in Figure 3.24. It is a general and almost “classical” Automatic Vehicle Monitoring (AVM) architecture based on typical systems and sub-systems, including: GPS system, long-range communication network (GPRS/GSM and PRN), WAN connection among the Control Room and the hardware devices located at depots, short-range communications for data downloading/uploading among the buses and depots devices (PCs), in-vehicle systems (on-board driver terminal and display, radio-modem, short-range communications unit, silent alarm device, connection with the ticketing machines, live voice microphone, display and loudspeaker for user information, etc.); and user information infrastructure (user information panels at bus stops, SMS user information service, etc.).

This architecture, together with the organisational structure required to operate the technical system and manage the daily operational complexity of public transport service production, has allowed ANM to develop and operate specific applications for providing citizens and public transport users with a set of information on both the conditions of the transit service and of other mobility and city situations.

Based on the experience developed at ANM for more than a decade this section aims to provide an overview of the benefits that can be achieved by an AVM system, both in general and, particularly, from the perspective of providing accurate and updated real-time information about the status of the public transport network and passengers services.

First, the sub-systems, components and technologies implementing the user information services of the AVM are introduced, taking as an example of such class of applications the system realised in Naples. Then, the benefits of AVM technologies and services are summarised from both the point of view of the Transit Company and the users. Further detail relating to the implementation of AVM systems is found in Chapter 7.

3.7.2 User information component and services: implementation in the Naples AVM

The real-time public transport management system realised and operated by ANM in Naples can be considered as a typical implementation of this kind, as regards both the general system and, particularly, the user information components and services it is comprised of. At present, this represents one of the most consolidated systems in Italy and is based on a series of services offered to the users both on-board the bus and at the stops. Overall, user information services are provided through:

- 120 “Infostop” panels located at the main bus stops;
- 30 electronic information displays in the shelters;
- On-board visual information about the next stop, provided through display or LCD monitor;
- On-board audio announcements about the next stop.

The electronic information panels, installed at the primary stops in the urban area, allow the Control Centre to automatically provide real-time information about the forecasted waiting time for the different lines, related to all buses passing the stop within the next 20 minutes. The Control Centre collects the location of each bus through GPS and a long range communications network and, on the basis of the distance from the



Figure 3.25: On-street public transport user information: Infostop panels in Naples showing (a) estimated bus arrival times and (b) service disruption information

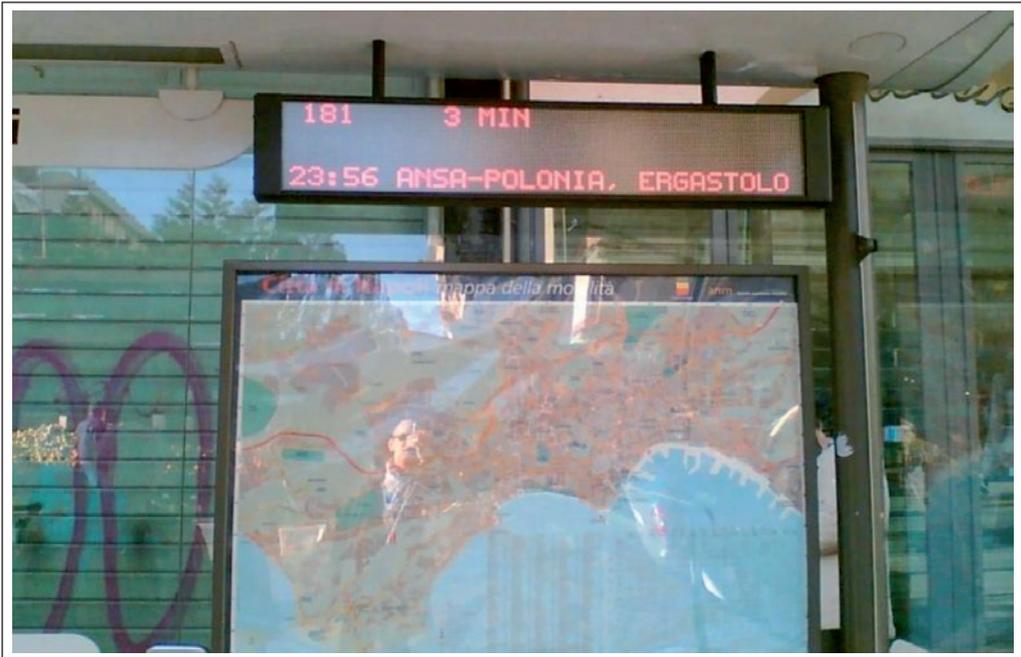


Figure 3.26: On-street public transport user information: electronic information displays at bus stop shelters in Naples

bus stop, of the journey path in operation and of the estimated travel time on each network segment (obtained from an historical database) it is able to compute the expected arrival time at the stop (Figure 3.25). When the bus actually approaches the stop, it executes a direct data exchange with the user information panel through a short-range radio communications system, updating the displayed bus arrival time information sent by the Control Centre. Once the bus doors are opened (and the event is communicated to the panel again via short range) the message on the expected bus arrival time on the panel is automatically deleted.

The control centre can also plan free text messages of a determined length for specific information to be sent, in real-time or at predefined intervals, to selected groups of panels; information may be related to, e.g., deviations, service disruptions, events affecting circulation (e.g. strikes, manifestations, etc.) and other specific information about the service (e.g. special lines, etc.). The same kind of information service is ensured through electronic information displays which are integrated in the stop shelters (Figure 3.26).

The panels and the electronic displays are essential service tools for providing information to the users and reducing their possible discomfort resulting from the waiting time at the bus stops. Furthermore, by providing timely and accurate service information such tools also reduce the uncertainties of the users waiting at the stop and consequently

improve the perceived quality of the transport service. Recent users' satisfaction surveys have clearly demonstrated the general appreciation of the service by the users, both as regards the reliability of the forecasted waiting time and for the timeliness of information provision.

In addition to "Infostop" and general information panels at bus stops, user information is also provided on board the bus usually by means of audio devices. This is mainly related to information about the next stop and is implemented as audio messages (recorded or synthetic voice) distributed through loudspeakers for the bus driver and the passengers as well as, in textual format, through message displays. This kind of service has proven to be extremely useful from the point of view of increasing public transport accessibility, as it addresses not only regular public transport users but also occasional users and the many tourists visiting the city, allowing them to get to know in real-time the sequence of bus stops along the line and providing additional indications about the most important points of interest in the area (monuments, museums, tourist areas, etc.).

Finally, user information is also provided by dedicated SMS services, which allow public transport users who have requested this, to get the estimated bus arrival times at a specific stop via an SMS sent to their mobile phones. This kind of service, which is at present common place in many cities in Europe, has been recently piloted by ANM also using Blue Tooth communications, with positive and encouraging results. Functionally similar to the SMS-based service, an implementation based on Blue Tooth technology has the advantages to provide the same service as that provided by electronic displays without infrastructure costs nor costs related to message transmission via the cellular network.

Once approaching the bus stop, the user owning a blue tooth mobile device receives, at certain time intervals, a message containing the information on the expected waiting time for the buses of the different transit lines. The service is free of charge for the users (contrary to current SMS based services) and the users are free to accept or refuse the messages.

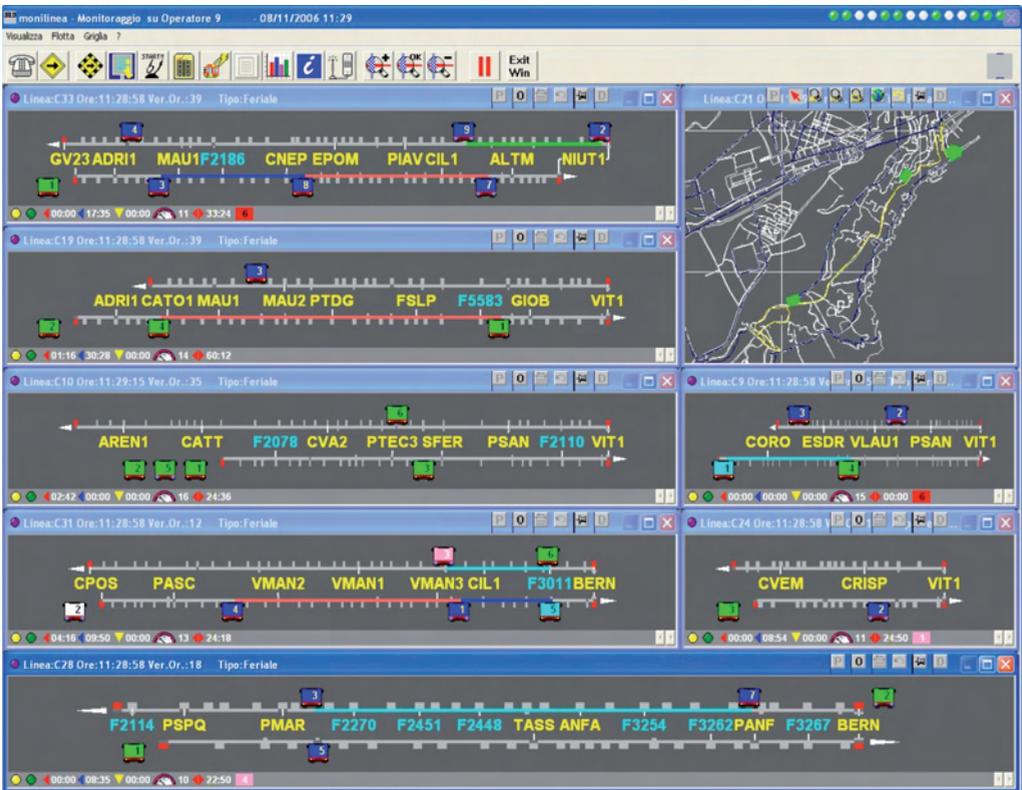
3.7.3 Benefits of the AVM system

Overall, by operating an AVM system for dynamic fleet monitoring and control, Public Transport Companies can achieve a number of important benefits related to various aspects, from operational efficiency, to service performance and regularity, to user information services. Looking particularly at user information and service quality, the main benefits can be summarised as follows:

- *User information.* As illustrated above, improved user information is clearly a main aid that can be obtained by the AVM system. The possibility to send real-time information to public transport users enhances significantly the perceived service quality. 111

On-street user surveys demonstrate that the waiting time perceived at the bus stop is of less importance when the foreseen dynamic arrival time is available. This aspect represents a very relevant factor also in relation to the transport service contract signed between the Transport Company and the Authority, as in this kind of contract quality indicators (generally, customer satisfaction parameters) are considered as factors influencing the service cost/payment schemes.

- *Service regularity.* AVM operation allows the Transit Company to achieve a higher capability and more timely control of service operation, increasing their abilities of preventing or at least minimising network inefficiency (i.e. reducing the impacts of road blocks, incidents, traffic congestion, line deviations, etc.). The positive effects on service quality (regularity) for the users are a direct consequence of such a higher control of service operation. Again, from the point of view of service contract management, this could reduce the risks of the Transit Company of running into penalties due to service inefficiency. Service regularity is checked and controlled in the Control Centre (Figures 3.27 and 3.28). In a network with high traffic congestion or critical



112 Figure 3.27: Display of lines data and service regulation in the AVM Control Centre

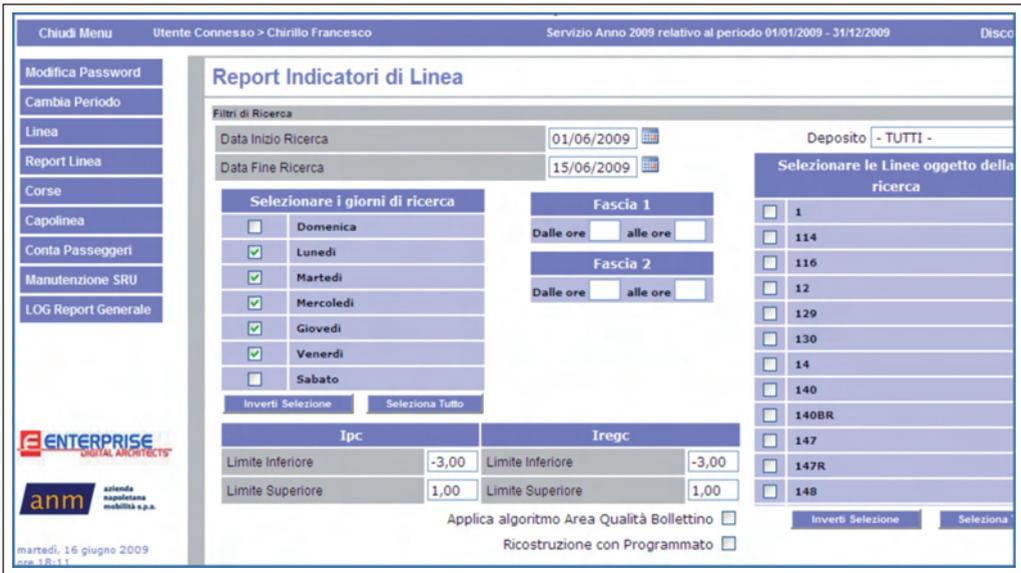


Figure 3.28: Service performance monitor in the AVM Control Centre

situations, the possibility to act with centralised micro-regulation commands on the lines/fleet allows significant improvement of transit lines regularity and punctuality.

- *Knowledge of service operation.* Related to company procedures, the AVM system provides a detailed knowledge of service operation situations. The analysis of collected data about the service can facilitate a closer adherence of the planned services to the real ones, as well as more suitable trips and travel time programming. For example, in the last year, ANM has obtained an increase of 6% of the commercial speed in comparison to the previous year, recovering more than 700 km/year.
- *Service performance.* The data collection and monitoring tools of the AVM system provide also a fundamental help in recording and analysing service performances. This enables the Transit Company to deliver detailed reporting to the Authority about service operations and performance in order to obtain service certification.
- *Costs optimisation.* The AVM communications infrastructure between bus drivers and the Control Centre provides a fundamental help in the optimization of data and voice communications costs. Furthermore, AVM technologies and services aid also in the optimization of the control team on the road, in the reduction/minimization of the control personnel at the terminals, the valorisation of operation control personnel and co-ordinators, professional development and qualification of the personnel dedicated to the control room. At ANM, the number of control personnel on the network was reduced from 250 to 120 persons in the last 5 years and the rate control person/driver has changed from 1 to 9 to 1 to 16, with a relevant compression of costs.

Figure 3.29: On-board driver terminal in ANM AVM system

- *Safety.* Travellers and drivers/controllers safety is also positively affected by AVM technology. Thanks to advanced driver terminal facilities such as emergency calls, silent ambient audio monitoring and recording through hidden microphones, the AVM system – better when integrated with a video surveillance system – enables timely reactions by the Control Centre in case of emergencies and on-board problems (Figure 3.29). This not only increases safety, but it also contributes to reduce significantly the assistance time.



Figure 3.29: On-board driver terminal in ANM AVM system

- *Vehicles performance.* Integrated with other on-board technologies (device monitoring and diagnosis systems), the AVM is a valid tool for monitoring the mechanical and electronic performances of the vehicle and for preventing the vehicle from breaking down, with clear benefits both on maintenance costs and on operation losses.
- *Working conditions.* The possibility of having permanent assistance combined with the greater regularity with reduction of inefficiencies and service monitoring (when appropriately exploited) contribute to improve the working conditions of the operators and as a consequence to increase their performance and working attitude.
- *Support in service tendering.* AVM monitoring and fleet management tools represent an added-value for the companies with respect to current and modern terms of setting

up tendering procedures, as they can help in defining (and evaluating) objectively the scores for service assignment.

- *Support in insurance processes.* Vehicle monitoring and tracking services of the AVM system can also help in insurance contract management, by providing certification tools that can be used for insurance purposes and for the management of incidents. After a long experience with the operation of their AVM system, ANM is currently evaluating the possibility to request a reduction of the insurance fee for the vehicles of their fleet.

3.7.4 Conclusions

AVM technologies and systems represent general tools that provide fundamental help in planning and operating complex public services such as public transport. Not only do such systems deliver essential instruments to manage the entire service process, but they also provide the building blocks for implementation and effective operation of user information related to the service, a fundamental element which has a major impact on the successful operation and public use and acceptance of the service.

ANM are operating the AVM system of urban public transport in Naples Metropolitan Area, providing services able to cater for some 175 million passengers in 2008. Taking as an example the case of the Naples AVM – which can be considered as a mature AVM installation typical for European cities of a comparable size – this section has provided an overview of the general user information capabilities of an AVM system – i.e. its infomobility component – highlighting its main features and general benefits. Public information services are considered by ANM as a main element for high level, high quality public transport provision, and efforts in this area are planned to increase in the years to come, based on the positive experience gained in over ten years operation of the present AVM system and in accordance with a general trend which is more and more visible in most sectors of mobility and transportation services.

3.8 User Information: the Vienna experience

M. Lichtenegger

3.8.1 Introduction

Wiener Linien is commissioned by the City of Vienna to plan, construct, maintain, operate, distribute, sell and market the bus, tram and underground network. Market share is extraordinarily high: 34% of all trips are made by public transport. The contract sets clearcut goals. Market share must be increased and in parallel costs lowered. Comprehensive integration is a key success factor. Therefore the company offers a ready

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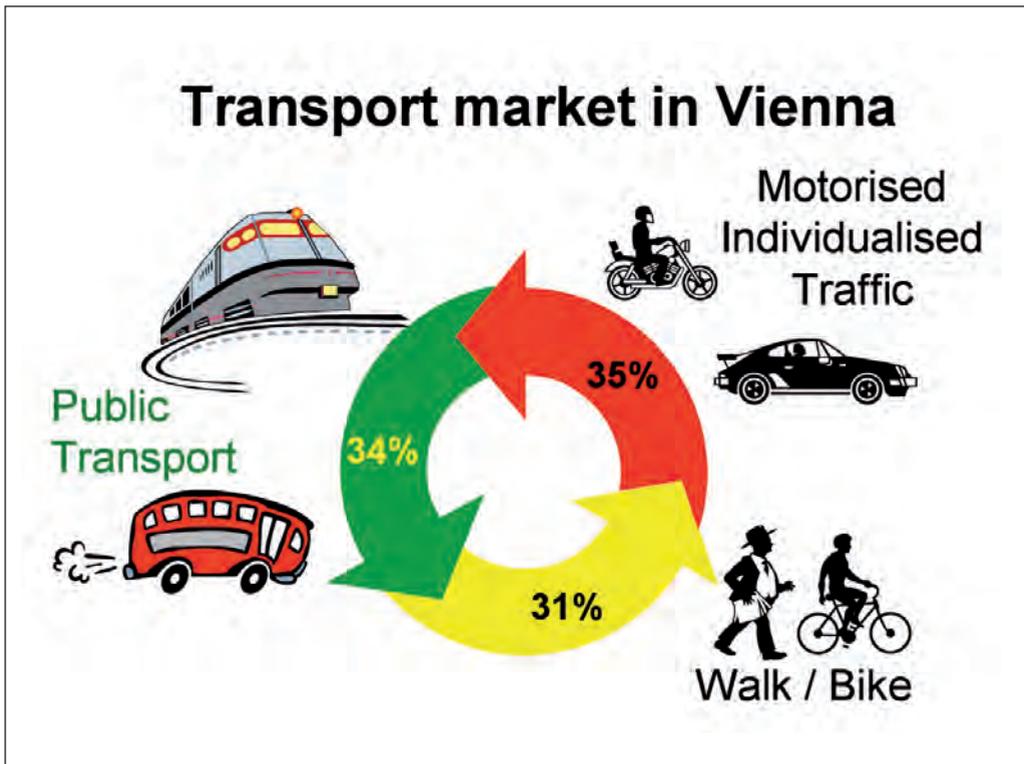


Figure 3.30: Modal split in Vienna, 2005

made mobility package tailored out of one hand. An overall and proactive marketing approach guaranties an optimum customer focus

One of the most successful marketing strategies of Wiener Linien is the “regular customers’ strategy”: Every 4th Viennese adult is an annual pass holder! The regular customers’ strategy goes hand in hand with the idea of an open system and a traditional ticketing strategy. Another important customer need is information. The company is therefore offering a wide range of proactive information services all of which are discussed here. The situation in the wider Vienna region is considered in Section 4.2.

3.8.2 Wiener Linien – Backbone of Vienna’s mobility

Vienna is Austria’s largest city (1.6 mio. inhabitants). Wiener Linien is still a “traditional” local transport company providing around 94% of all transport services in Vienna. The City of Vienna is the 100% owner of Wiener Linien. The company runs 5 underground lines, 32 tramway lines and 80 bus lines. Some 7,800 employees are engaged in offering reliable services to the customers on nearly 1,000 km net length.

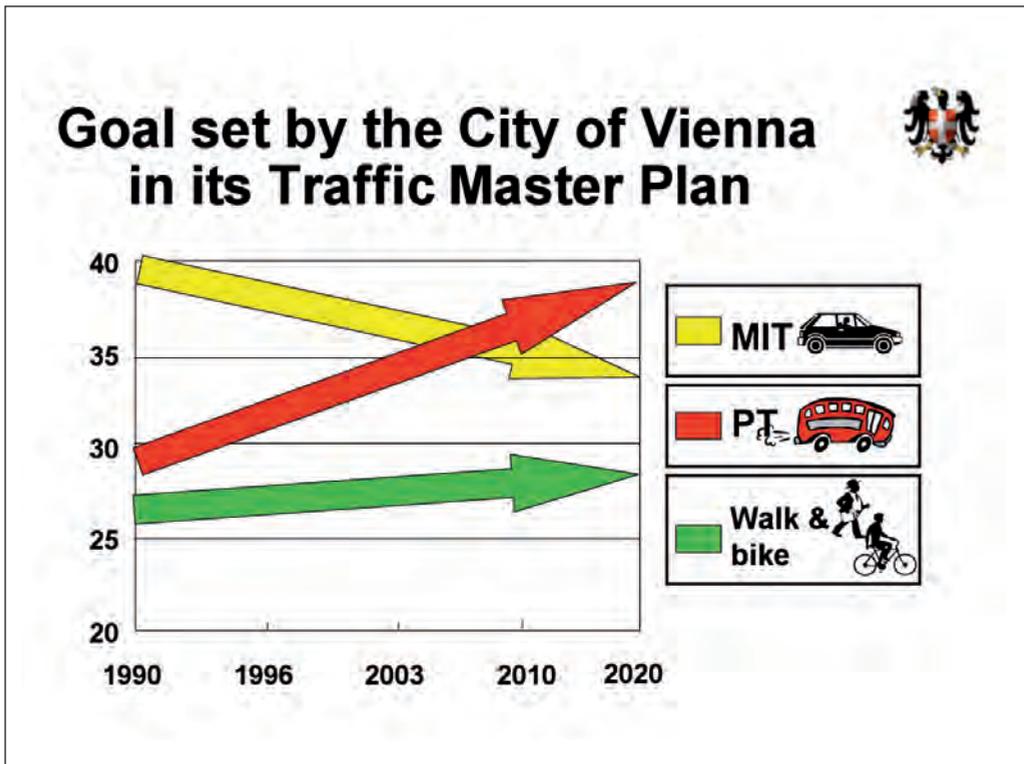


Figure 3.31: Traffic Master Plan Vienna, 2003

Market Share

Wiener Linien increased public transport market share from 29% in 1993 to 34% in 2005. At the same time market share of individualised motorised traffic (car traffic) decreased from 40% to 35%! 31 % of all trips are made by foot or by bicycle. Compared with most other big cities in Europe and all over the world this is an excellent high market share of public transport.

Ridership

Just as in other all European metropolises, the availability of private cars is constantly increasing in Vienna. After the Second World War, the passenger turnover of public transport began to drop, as in fact everywhere else. However, since 1975 the passenger volume has been continuously on the rise again. Approximately 2 million people per day travel with Wiener Linien which makes 747 million passengers per year.

Vienna´s Traffic Master Plan

In spite of the excellent results compared to other cities in Austria and abroad the "Traffic Master Plan" of the City of Vienna aims at raising the share of public transport to 40%

in 2020. In order to meet this goal the City of Vienna worked out a “Traffic Master Plan”. The measures defined in this plan are

- “smooth” restrictions for individualised motorised traffic
- proactive measures for walking and biking
- proactive measures to increase ridership of public transport:
 - by developing the successful metro system
 - by implementing a consistent customer focus
 - by improving quality of service and network
 - by improving public awareness, image and level of information
 - by enforcing intermodality: Car drivers use public transport!

Change of general conditions

For 100 years public transport was financed by the City of Vienna via the idea of “loss-compensation”: At the end of the year Wiener Linien knew what it cost, and whatever the total amount of money was, it was paid by the City.

But the frame conditions of the public transport world have dramatically changed. The City of Vienna has contractually commissioned Wiener Linien to render public mobility services until 2009 with an option to extend the agreement. The agreement charges Wiener Linien with the operation of bus, tram and Underground lines in keeping with a stipulated quality level but at the same time reducing costs. As everywhere communal bodies face restricted and tight financial means. So costs of public transport must be lowered and for the first time Wiener Linien bears the economic risk fully by itself.

3.8.3 Comprehensive integration as success factor in traffic management

The only way to compete successfully with the motorised individual traffic is to provide high quality and to meet the demands of the customers. Mobile citizens expect full service mobility. They do not want to deal with details such as non-integrated lines and different tickets and fares. Instead of thinking about the mode of transport to be chosen, passengers ask for a ready and well prepared mobility package of high standard. Comprehensive integration is a key-success-factor in traffic management. Therefore the City of Vienna decided to put Wiener Linien in charge of the whole mobility system.

In Vienna the city tries to realize an optimum level of vertical integration of political responsibilities and public services in parallel with a horizontal integration of all measures of a public transport actor like marketing, ticketing and sales, quality management, transport services, construction, operation and maintenance of infrastructure and rolling stock.

Wiener Linien therefore sees itself as a full mobility service supplier who provides the optimal vertical and horizontal integration of all these process elements, tied up for two key target groups: the municipality and the existing and potential customers. This way

an attractive traffic service can be offered to all potential customers who are willing to pay an adequate price for as many as possible journeys

Public Transport IS a MARKET

Fewer and fewer people have no choice but to use public transport. Far into the 1980s, the role of public transport companies was viewed as that of a mere provider of “essential” services – a provider that did not have to win and keep the loyalty of customers according to normal market rules. In 1993, still roughly half of all customers of Wiener Linien were forced to use public transport because they had no alternative. By 2004, this 1:1 ratio had changed dramatically to a 4:1 ratio: today, nearly four fifths of the passengers of Wiener Linien use the services because they have individually and freely chosen to do so. They could decide for other forms of transport if they wanted to, because alternatives do exist. Thus only one fifth of customers are actually dependent on Wiener Linien services (Figure 3.32).

The traffic market is increasingly a free market like any other consumer market. The only way to compete successfully with the motorised individual traffic is to provide high quality and to meet the demands of the customers.

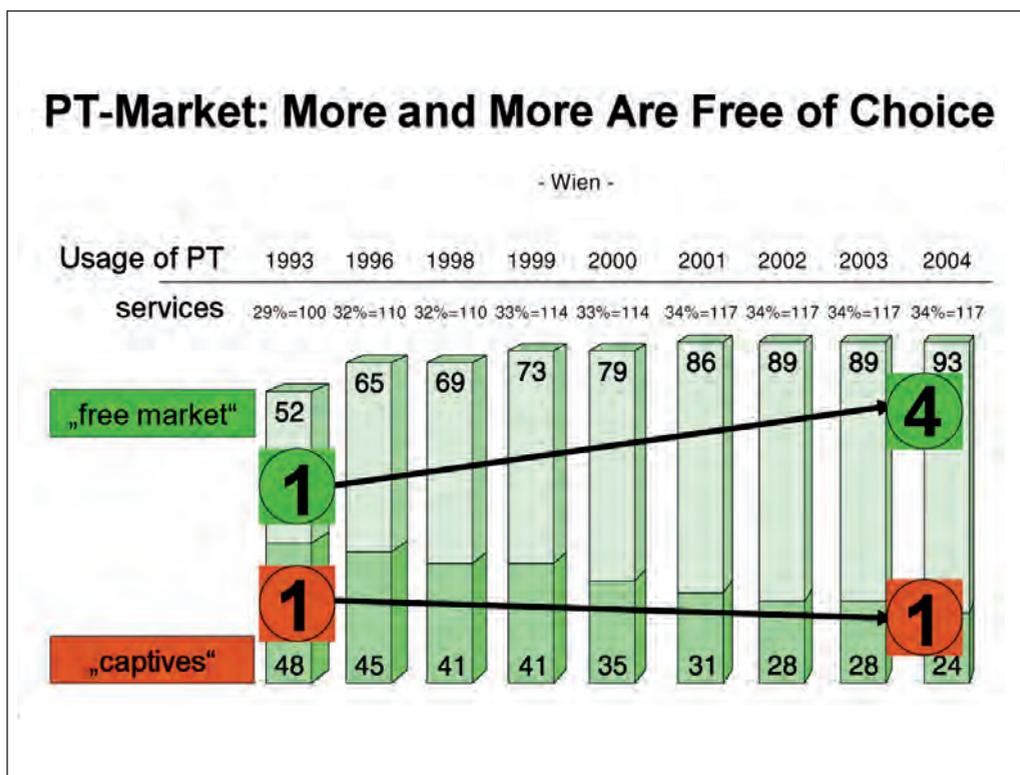


Figure 3.32: Usage of public transport services, Vienna, 2004

Integrated overall marketing strategy

To win new customers who are free of choice, but first of all keep existing customers who have individually and freely chosen to do so, is exactly the same job and situation as in any consumer market. One of the state-of-the-art tools which promise success in such a completely usual market situation is marketing.

However, marketing must not be based solely on communication measures; on the contrary, marketing strategies have to influence all strategies and activities especially of a service provider like a public transport company. Exclusively this way guarantees a consistent focus on the customer's view, which leads to a homogenous brand, and so marketing strategies and marketing measures are able to ensure the success of the company. Success in this case means: increasing market share, increasing amount of passengers, increasing incomes and optimised economic success.

Regular Customers are "efficient"

One of the most important, most consistent and longest lasting marketing strategies of Wiener Linien is the "regular customers strategy". We introduced the annual pass in 1982. Since then the number of regular customers buying annual passes increased steadily. Nowadays more than 300,000 people are holders of an annual pass.

That means that every 4th Viennese adult is an annual pass holder, which is an incredibly high market share, nearly on a level of market saturation. Indeed this is an extraordinarily high market share.

Therefore, despite "modern" trends in Europe we declare for retaining an "old fashioned", traditional ticketing strategy.

Several good reasons enforce the focus on this "regular customers strategy" in future:

- It's much easier to keep existing customers than to win new customers. To win new customers needs a 6 up to 11-times higher effort compared to keeping existing customers!
- Marketing-investment for keeping a "loyal": €0,91 or 0,22 % of turnover
- Low production costs: Regular customers are travelling more and more in off peak hours
- Nice experience → good image: Regular customers are making 'nice' leisure-time trips
- Regular customers are definitely more satisfied. An international benchmarking project shows this quite impressively as a general phenomenon all over the world. Another Viennese opinion poll shows that in average 82% of all customers are satisfied with Wiener Linien services, but out of the annual pass holders perspective 92% are happy with our product! (Figure 3.33)
- In addition, regular customers are better informed: Approximately half of the average citizens are well informed about public transport services, whereas nearly two thirds of annual pass holders feel quite comfortable with quality and availability of information (Figure 3.34).

Regular customers are more satisfied

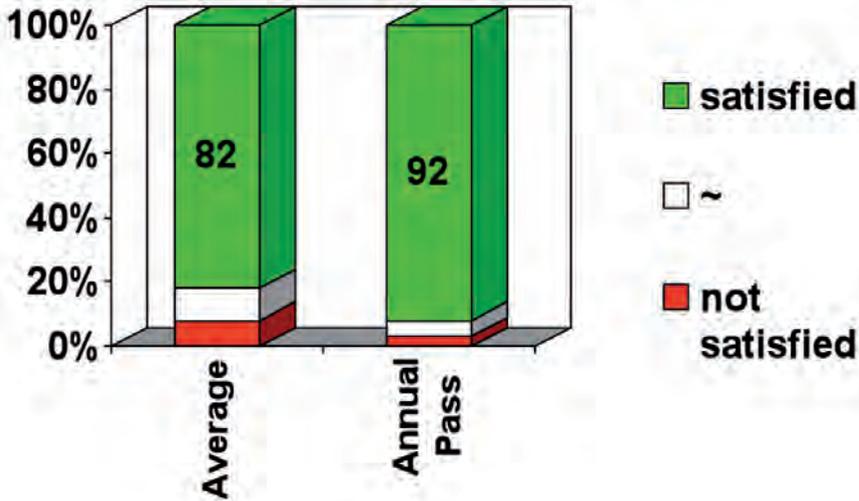


Figure 3.33: Satisfaction Ratio, Vienna, 2005

Wiener Linien keeps up a traditional strategy: “just come in and ride”

This strategy goes in parallel with the design of our system which is an open system showing some big advantages: It gives the impression of a “warm welcome”, it is user friendly and easy to use, it is the cheaper infrastructure solution for high frequencies and it is safe in case of disruptions. On the other hand fraud might be an issue and it’s harder to keep out people not being welcome around the system. Up to now more pros than cons ensure that this strategy is maintained rather than following the common trend of introducing smartcards.

Nevertheless Wiener Linien is, in addition, offering new electronic distribution options. For example two types of mobile phone tickets are available since 2004 although only a few people are willing to buy tickets this way.

Modern IT-technology improves quality management

From the customers point of view reliability, punctuality and regularity are key attributes of public transport services. To achieve these quality goals a modern IT-tool monitors some 1,000 tram cars and buses in peak hours. Collecting all on-line vehicle data ena-

Regular customers are better informed

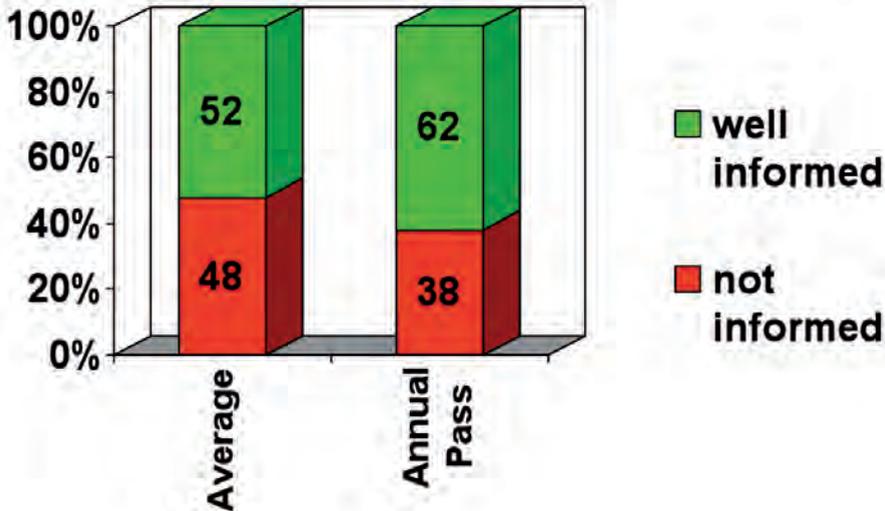


Figure 3.34: Information level, Vienna, 2005

bles the provision of a “count-down-information service”. Customers appreciate this service - but the company is not able to finance displays on every of their 4,400 stops. Therefore we plan to introduce a new service in summer 2006, which offers count-down-information via mobile phones.

3.8.4 Conclusion: Optimum information level as the key success factor

For many years, information could only be disseminated across the various channels according to a kind of “hit-and-miss” principle. The new information technologies enable us to supply the right person with customised information at exactly the right moment. This opens up a new dimension of customer relationship management – with individualised on-line information that is fine-tuned to fit the respective customer profile. Today we are offering information services face-to-face, via call-center, via W@P-services, via the internet, via public terminals and via below-the-line actions. The Wiener Linien homepage records more than 3,000,000 requests per month on schedules and service offers as well as 1,000,000 requests for global information.

3.9 ITS services for mobility management in Cagliari

E. Angius, S. Angius, B. Barabino, S. Farris, P. Tilocca

3.9.1 Introduction

Transport is a key factor in modern economies and society but there is a permanent contradiction between society, which demands ever more mobility, and public opinion, which is becoming increasingly intolerant of chronic delays and the poor quality of some transport services (EC, 2001). This fact underlines that while transport demand is increasing the supply system is not sufficient. For example in USA highway travel continues to grow as population increases especially in metropolitan areas. Between 1980 and 1999, vehicle miles travelled increased 76 percent while road expansion to meet this demand has lagged behind. The Texas Transportation Institute estimates that, in 2000, the 75 largest metropolitan areas experienced 3.6 billion vehicle-hours of delay, resulting in 21.5 billion gallons in wasted fuel and 90.2 billion € in lost productivity (Lomax and Shrank, 2002). Public transport use is also on the rise, reaching 9.4 billion trips in 2000, the highest level in 40 years (AAVV, 2002a). Goods transport are forecast to grow by about 69 percent between 1998 and 2020, from 15.3 billion tons, to 25.8 billion tons annually (AAVV, 2002b).

A similar situation exists in Europe. For example, average personal mobility increased from 17 km a day in 1970 to 35 km in 1998, the trans-European transport network suffers increasingly from chronic congestion because 7,500 km (10% of the road network) is affected by traffic jams every day, 16,000 km of railways (20% of the network) are classed as bottlenecks (EC, 2001). Largely considered a big-city problem, congestion and related delays are becoming common in small cities and some rural areas as well because mobility is actually an acquired right. This increasing demand for transportation is causing the transportation system to reach the limits of its existing capacity.

In this context the best strategies to improve the public and individual mobility and therefore to increase commercial speed, improve reliability, infomobility and ticketing can be found from:

- realization of new infrastructures that are characterized by high investment and management costs but slow to realise;
- use of new technologies (ITS/ICT) that are characterized by limited investment and management costs.

In fact, building new transportation infrastructure carries 3 negative aspects because it is expensive, can be detrimental to the environment and in urban areas it is becoming physically impossible to build enough new roads or new lanes to meet transportation demand. Moreover, transport to-day transgresses sustainable development (Gudmundsson and Höjer, 2002) and lacks elements to reverse the increasing tendency of traffic

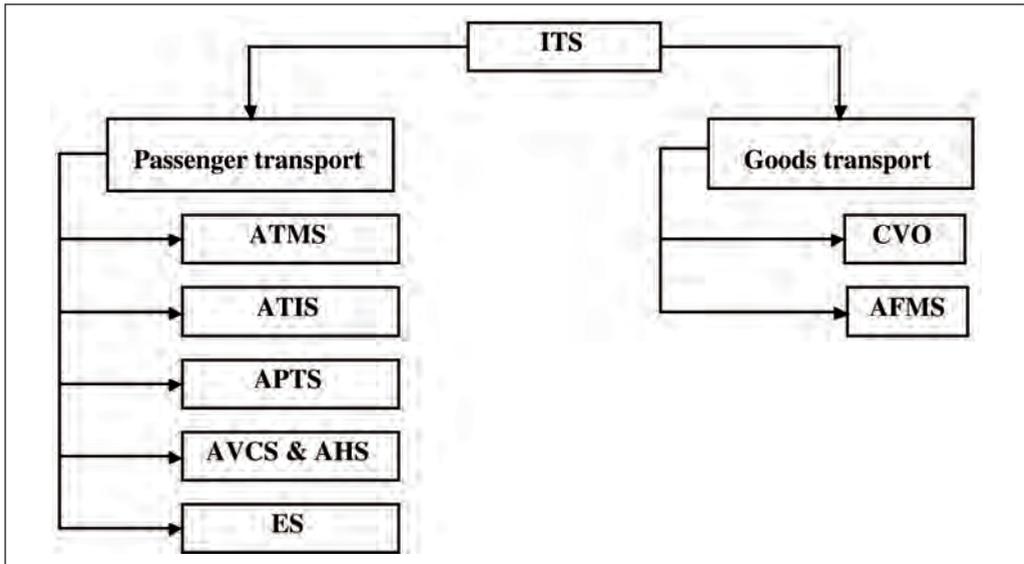
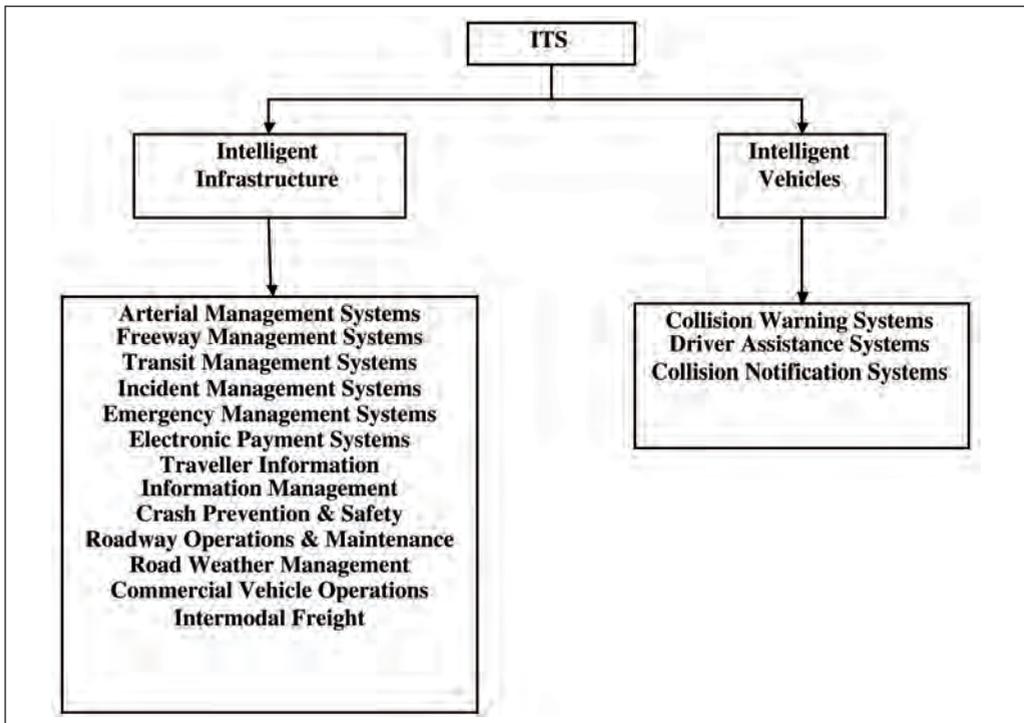


Figure 3.35: ITS classification using scientific literature



124 Figure 3.36: ITS classification using American literature

volumes. By 2010 an increase of 50% of CO₂ emissions over 1990 is expected - 28% of such emissions are from the field of the transport (EC, 2000).

By applying the latest technological advances to our transportation system, ITS can help meet increasing demand for transportation by improving the quality, safety, and effective capacity of our existing infrastructure (Maccubbin et al, 2003). Therefore the idea is to apply ITS procedures, systems and instruments that concur, through the collection, communication, elaboration and distribution of information, to improve the transport and mobility of persons and goods and to verify and quantify results, the latter can be achieved using substantially two methods, goal oriented approach or economic approach (Gillen et al, 2009; Peng and Beimborn, 2000; Peng et al, 2000). A goal-oriented approach is likely to be used at the local or district level for project selection and identification, the economic approach is most likely to be used at a general or global level for project selection.

Scientific literature (Crainic, 2006) groups ITS into the two areas of passenger and goods transport (Figure 3.35) and comprises Advanced Traffic Management Systems (ATMS), Advanced Traveller Information Systems (ATIS), Advanced Public Transportation Systems (APTS), Advanced Vehicle Control Systems (AVCS) and Automated Highway Systems (AHS), Emergency Service (ES), Commercial Vehicle Operation (CVO) and Advanced Fleet Management Systems (AFMS). The American model (www.benefitcost.its.dot.gov) groups ITS into two categories with Intelligent Infrastructure and Intelligent Vehicles divided into programme areas and specific ITS application areas (Figure 3.36).

Classification using the American model cannot represent all aspects of ITS for two reasons:

- many of the programme areas can be dependent on or heavily influenced by other areas and this dependency is not well shown.
- many ITS programme areas share information and operate in a co-operative manner which is difficult to capture in this format. For example, traveller information systems must rely on surveillance data collected by other ITS applications such as freeway, arterial, and transit management systems. In addition, in-vehicle driver assistance systems, such as navigation, can be augmented by a co-operative infrastructure to provide routing and/or travel time information to vehicle systems.

Therefore it is preferable to refer to the first classification in Figure 3.35.

In this context two relevant projects, *POR* and *AGATA - ImoSPro* are relevant (Tilocca et al, 2006). The first project "Integration and technological development of mobility control systems in Cagliari area" aims to create a telematics platform in order to control and manage public/private traffic in the Cagliari area. The second is an important project which has analysed inner area mobility needs in order to generate a multi-service infomobility Agency demonstrator to give user information in several ways.

This section describes the principal results of these projects. In particular Section 3.9.2 presents the reference context with its problems; Section 3.9.3 discusses the POR project while results achieved in the AGATA - ImoSPro project are described in Section 3.9.4. Finally, Section 3.9.5 presents key findings and some conclusions.

3.9.2 Reference area

The reference area situated on the south of Sardinia Island comprises a vast zone formed by a central metropolitan nucleus where the city of Cagliari represents the main centre of attraction, surrounded by several towns of middle and large dimensions that generate a high daily mobility. Table 3.1 shows data about mobility, modal distribution and public transport supply from the towns examined and analysed together with other towns and villages which are connected with them. In particular, the motorisation rate is 660 vehicles per inhabitants (AAVV, 2003; AAVV, 2004; Corona et al, 2003) and usually the most central city streets have shown a high level of congestion due mainly to:

- territorial topography which conditions road development (in this case it is important to underline the presence of sea, ponds, hill zones, etc.);
- territorial discontinuity on account of the number of municipalities;
- lack of integration between public and private transport;
- low commercial speed (16 km/h for public transport and 20 km/h for private transport);
- lack of park and ride;
- a reduced use of public transport due in part to the lack of busway and bus lines (with flow and contra flow) that they represent only the 5% of public network.

Mobility in wide area of Cagliari (2005)	
Resident inhabitants	366,687 inhabitants
Surface	402.1 Km ²
Municipalities Involved	10
Number of cars	214,874
Number of buses	1,318
Motorisation rate (Cagliari)	0,660
Daily Journeys toward Cagliari	141,470
Modal distribution (2001)	
Motorized individual transport	82 %
Public transport	18%
Public transport supply (CTM Company)	
Network length	310 Km
Total line length	480 Km
Inhabitant supply	31.5 Km / year inhabitants
Lines	29 (3 trolleybus)

Table 3.1: Some data about mobility in the Cagliari area
(Source: AAVV, 2004; CTM, 2005; Corona et al, 2003)

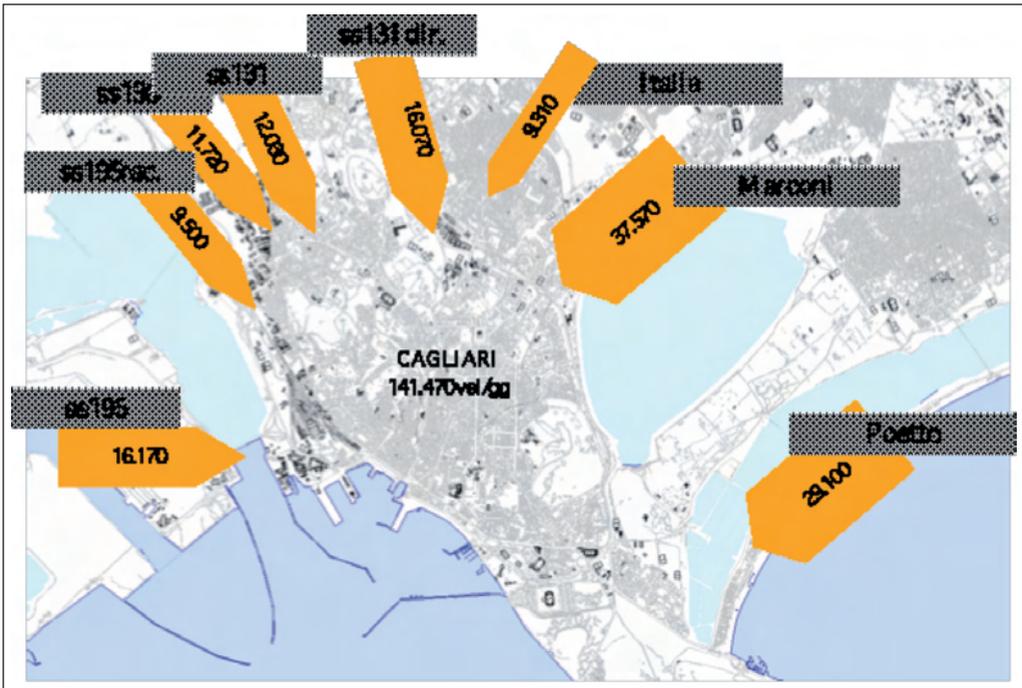


Figure 3.37: Area-wide mobility (Source: Authors)

As indicated in Figure 3.37, the mobility demand is of a central tendency type (towards the leading centre) that involves a territory with transport infrastructure already largely used in the inner area. Such a pattern of mobility is spread across the territory and because of the lack of a collective transportation system close to the destination, the only system of transport which can be used instead is the private vehicle. The road network inside the town is often already congested with traffic and so unable to sustain the requirements for mobility within the inner city.

3.9.3 *POR Project - Integration and technological development of mobility control systems in Cagliari area*

The POR Project— Integration and technological development of mobility control systems in Cagliari area – was approved and financed on the Regional Fund (POR Axe VI Nets and service nodes, Mes. 6.2 “Accessibility and government of mobility in city contexts”) for an amount of €9,873,000. The project ran between 2004 and 2008 and addresses the realization of a telematics platform applied to transport in the wider Cagliari area. With the platform it will be possible to manage both private and public transport (AAVV, 2001; Corona et al, 2003).

A brief state-of-the-art on telematics platforms

Systems to manage individual and public mobility are operating in many European contexts. Examples include London, Turin, Berlin, Munich, Glasgow, Barcelona, Madrid, Goteborg and Stockholm (Rupert et al, 2003). The Madrid Traffic Control Centre controls 1,000 intersections with a hierarchical control system using three levels. At the lowest level, each sub-centre controls 20 to 24 intersections. Moreover there are Closed-circuit TVs (CCTVs) in 40 critical intersections.

The centre can change control strategies, inform the public, share information with commercial radio stations, connect to TV stations, and control VMS and the Internet, which is often used by fleet operators. The website (www.cities.munimadrid.es/mapatraficovi.asp) presents volume data on arterials and parking lot status. The Consortium Transport Madrid (www.ctm-madrid.es) oversees the subways (Metro), buses (public and private), and regional rail. Some buses are equipped with automatic vehicle location (AVL) and “next bus” arrival systems. The information is not integrated with traffic information and there is not a system to manage access control and the environment. In Turin, 5T (www.5t.torino.it/5t/) manage private and public transport flows. The telematics platform comprises 10 intelligent sub-systems like Urban Traffic Control in ATMS area, public transport in APTS and Variable Message Sign in ATIS. Because Turin was probably the first city in Europe to install an advanced traffic responsive UTC system in which public transport priority formed an integral part of the system design (1992), the technology used to manage public transport is beacon-based AVL, with radio communications (polling) between public transport vehicles and the control centre, and is now a little obsolete. Other cities have developed ITS systems based substantially on ATMS, APTS and ATIS.

Local Consortium, objectives and project phase

The main objective is to control and manage public and private traffic through mobility co-ordination (public and private) using several components of ITS like junction control (Urban Traffic Control), fleet management, parking management, VMS, Access Control, Environmental traffic management, services for public and private users (Internet). This project is characterized by high complexity and involves several partners such as:

- CTM and Cagliari municipality in order to define guidelines about the project and verify administrative and management issues;
- technological partners (i.e. the TechnoMobility Consortium) in order to take care of technical development.

The project was articulated in 2 phases: experimental and realization. The first was completed in 8 months and was necessary in order to underline problems and solutions before realization. The second was shared in four contracts in order to reduce risks.

Technical description and innovative aspects

Based on Turin's experience, the project aims to realize a telematics platform which is constituted by 10 sub-systems integrated using the architecture shown in Figure 3.39. With reference to the classification used in Figure 3.35, it is possible to group them as shown in Figure 3.38.

Sub-systems are linked by a four level architecture that comprises at vertical level a central management level represented by two centres (S1 and S2), a central operation level (single architecture of other sub-systems), and a local level represented by every necessary device. At the horizontal level communication is rendered operational by optical fibre between S1 and S2, GPRS and ADSL where optical fibre is not available. A modular and flexible structure is carried out, where sub-systems are independent for the solution of problems of their own competence, but they interact between every sub-system and assure information and data transmission in order to manage critical aspects and develop functional synergies. An open architecture is carried out which is possible to implement step by step.

This architecture underlines a double complexity in the vertical order into a single sub-system and in the horizontal order between sub-systems: in fact a vertical development is necessary for every sub-system of architecture which has to assure a complete functionality of sub-system components and, a horizontal development between sub-

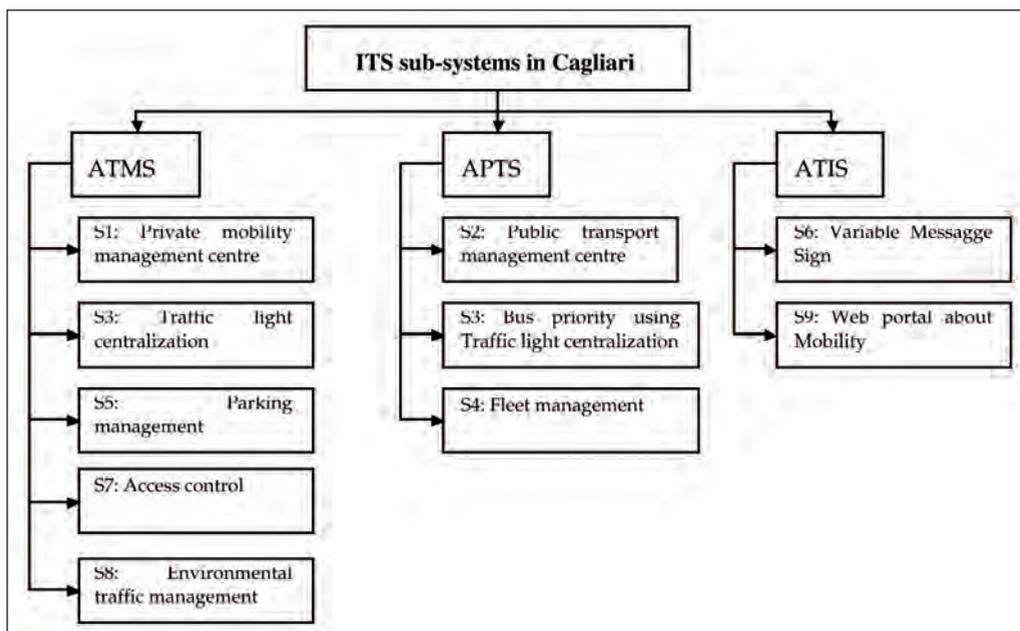


Figure 3.38: ITS Sub-systems in Cagliari

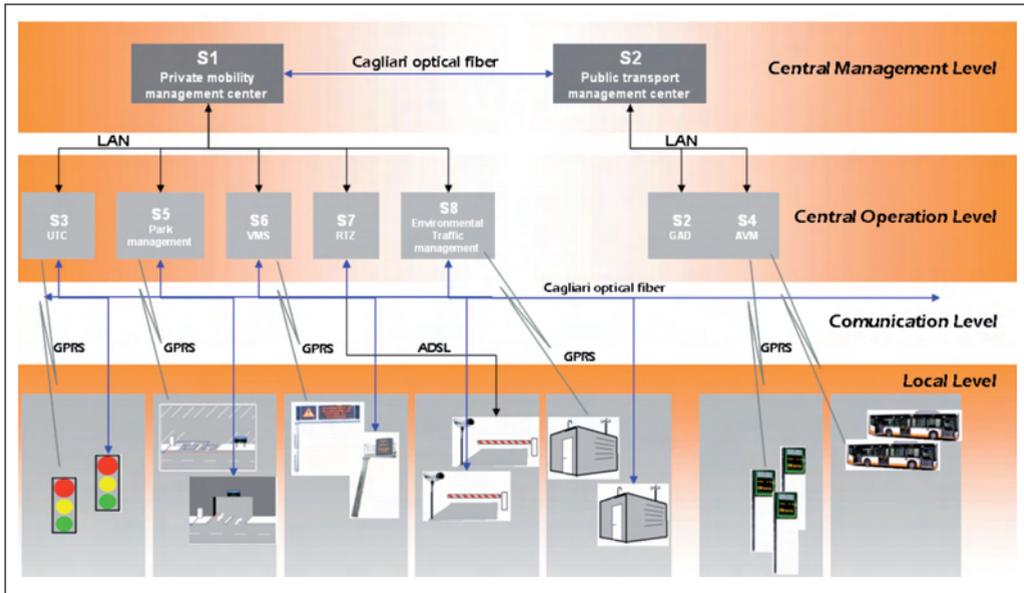


Figure 3.39: Telematics platform architecture

systems because a high co-operation level in terms of data exchange and communication is fundamental.

This complexity can show four principal innovative project aspects, namely:

- an elevated interdependence level between several sub-systems: in particular they are realized with a modular and flexible structure in order to enable a development toward functional blocks;
- the realization of an integrated system which enables communication and data exchange between devices of public and private transport in order to manage their traffic with an integrated vision. In particular through a single network it is possible to ensure and manage public and private traffic flows and so resolve area critical aspects thanks to a coherent vision;
- a high level of technological innovation both from infrastructure and system vision point of view. This system can be a prototype of an integrated architecture;
- the telematics platform specificity which is conceived like an open system which ensures the continuous evolution of system with advance of technologies and new competences. This opportunity would be denied by use of closed packages available in specific fields but soon obsolete and without some possibility of increase and therefore of competitive advantage.

Some indication about costs

130 Table 3.2 shows the budget division foreseen at inception.

Sub-system	Cost
S0	€ 637.824,00
S1	€ 1.143.952,00
S2	€ 335.697,00
S3	€ 1.451.244,00
S4	€ 3.441.669,00
S4.1	€ 645.571,00
S5	€ 604.255,00
S6	€ 836.660,00
S7	€ 676.559,00
S8	€ 1.181.653,00
S9	€ 702.381,00
Total	€ 11.657.465,00
IVA	€ 2.331.493,00
Total cost	€ 13.988.958,00

Impact index	
Public transport supply increase	15%
Public transport use increase	15%
Private vehicles reduction (into 3 year)	17%
Public transport commercial speed increment	20%
Private transport commercial speed increment	16%
Saving average travel time on public transport	15%
Saving travel on board time for user	6 min.
Saving average travel time on private transport	20%
External cost reduction	15%
Work places created	12-18

▲ Table 3.3: Impact index expected

◀ Table 3.2: Budget division between sub-systems (project) at Sept 2002

Expected results from the Project

The project previews an integrated series of participation and management of the impacts from public and private traffic in the city area. In particular the total project strategy aims to carry some benefits in terms of:

- congestion reduction;
- atmospheric pollution reduction;
- improvement of public transport performance;
- improvement in citizen mobility through provision of real-time information.

Starting from these benefits some reference values are foreseen (Table 3.3).

3.9.4 The AGATA - IMoSPro Project

The IMoSPro Project –Intelligent Mobility Service Providers– was approved and financed by the European INTERREG IIIB Programme in the MEDOCC area. The project ran between July 2004 and June 2006 (Barabino, 2006). This project constitutes the local AGATA project developed in Cagliari (Frosini et al, 2004). The AGATA IMoSPro project foresees the feasibility study of a multi-service infomobility Agency which co-ordinates mobility services in urban areas and development of some demonstrator services which can be used in this context. Within the Agency processes of management and co-ordination

will be based on information and communication technologies and on services which will allow integration and interaction between service, actors (operators and users) and the Agency itself. To understand the aims and objectives of AGATA it is important to have an idea of the context in which the project was developed. Further ideas relating to the Agency approach are discussed in Section 3.11

A brief state-of-the-art review on traveller transit information systems

Previous studies in Sweden (Höejer, 1996 and 1998) have explored possible scenarios to facilitate the change towards a sustainable transport system. Results show that a public information centre is appreciated. Scientific literature (TRB, 2003) classifies TTI in different ways but the more common classification groups them on the base of the period of travel in which information is received. In particular they are:

- TTI pre trip (before beginning the travel);
- TTI en route (in stopped/station, along road);
- TTI in-vehicle (on-board).

Pre-trip information is information that a passenger accesses before starting on his or her trip. It covers several areas such as route alignments, schedules, arrival times, delays, itinerary planning, and multi-modal information. Hence TTI plays a critical role in the user's decision on which mode to take, when to make the trip, what route to take, and how to get to his or her destination. Usually pre-trip information includes static information on routes, schedules, fares, and system policies, and itinerary planning but lately it is possible to receive dynamic pre trip information on web sites such as BusView (http://busview.org/busview_launch.jsp), Washington State Ferries (<http://www.wsdot.wa.gov/ferries/>), etc. Historically, the main source of this type of information has been printed schedules, maps, and other materials displayed at rail stations, at bus terminals, and at bus stops. Now TTI is now provided via the telephone, Internet websites, wireless media, and public kiosks.

Providing en route transit information plays a significant role in keeping travellers informed about the status of their vehicles; reducing their anxiety; and directing them to the right stops, platforms, and bays. Real-time information describes current transit operations such as updates on delays, incidents, and service diversions along transit routes, as well as estimated vehicle arrival and departure times for stops along the routes. The main source of this type of information is represented by dynamic message signs along routes.

In-vehicle transit information provides important information to travellers while they are en route. In-vehicle information has two functions: to help people with disabilities during their trip and reassuring passengers that they have taken the right vehicle and route. This type of information is printed in on-board displays and with audio formats.

132 Experience in several contexts (Barabino, 2007; TRB, 2003), underlines:

- travel information is not distributed by a single centre, usually they are supplied by a single Agency;
- en route information is distributed through the company that manages the service who is usually the owner of the vehicle.

TRB research (TRB, 2003) indicates possible strategies of improvement for the TTI future such as:

- to improve data that constitutes the base of TTI in terms of level of detail, cover, accuracy and maintenance;
- to realize a complete integration with other systems of information to the traveller including public - private;
- to supply personalized information for customers at several levels;
- to supply information in real-time using many channels so as to increase customer flexibility in completing the travel.

In order to guarantee best accessibility to the information system about public transport it is necessary: to study and to plan an integrated information centre on local public transit, to make available the greater number of TTI in order to increase information accessibility, to make it available (static and in real-time) through a greater number of channels. This is the base of AGATA project in Cagliari carried out by the *Technomobility Consortium*

Local consortium, objectives and project phase

The global objectives of the local AGATA project were:

- the study and development of a database for the collection and harmonisation of data and information on the local public transport supply
- to make data available and accessible through innovative and modern facilities to private users, operators and specific Council boards and any other interested user.

Some strategic objectives that can be created with the support of the Agency are identified as to plan a centre of integrated services as an added value for the management of public and private traffic in metropolitan areas, to improve urban traffic flows through the availability of mobility services and to collect and analyse significant data for supporting measures in planning and organising infrastructure and transport services.

The project carried out research and surveys concerning urban mobility needs in order to arrange a prototype system of a mobility service provider, for providing services at added value concerning the urban public and private transport. Features include information functionality to improve the service, information on timetable schedules and connections with other operators, information on the state of service, waiting time at the bus stops, and network graphic display.

This project was articulated in 3 phases:

- analysis of local site needs;
- feasibility study;
- pilot project (three demonstrators).

In the first phase the principal local site needs were considered in a preliminary analysis carried out through meetings with local authorities and the public transport company. During the development of the local project a feasibility study was elaborated and 2 economic analyses (Revenues – Cost - Analysis and Benefit – Cost - Analysis) to evaluate the economic feasibility of the project was carried out. A total of 3 different demonstrations were developed: Demo 1 - Customised information supplier, Demo 2 - General information supplier, Demo 3 - Different fleet data collection and management. Finally, an exchange of experience on local project and dissemination in order to diffuse project results was necessary.

Analysis of local site needs

In order to carry out an analysis on the local site it was necessary to pose some preliminary questions, as following:

- Is it possible today to plan travel with several carriers or using different modalities of transport?
- Is it possible to obtain information on an integrated fleeting transport service?
- Does an integrated portal information about passengers transport exist?
- Do innovated instruments exist to approach this information?

In order to achieve the AGATA project activities, these questions must be addressed. It was therefore important to contact public transport companies to confirm what software is mainly in use for planning and programming by each company, examine the possibility of creating a data warehouse which provides an integrated supply of transport information and assume possible solutions for sharing the relative data on local public transport supply. The real problems found with respect to such contacts were the following: wide variety of different software used, various forms of data export, cartography not universal, little availability of dedicated informed systems: different database structures, low number of specialist resources (AAVV, 2005).

Through local site analysis users needs and institutional aspects emerged. Customers and user needs must be emphasised in order to understand the necessities of the site for the Agency services.

The feasibility of the Agency provided within AGATA fits into this context and the following is a description of the areas of intervention:

- collection and harmonisation of the supply database: previous investigation on the current situation and identification of a universal standard for data export and database sharing

- design and access to transport database; identification and authorisation system that allows uploading and updating data relating to the transport supply
- internet Portal: services and information are available in the website
- communication pushing systems: automatic integrated system for messaging in real-time
- fleet Location and control.

Feasibility study

Starting from this preliminary analysis a feasibility study was carried out and organised into several activities such as benchmarking on in-vehicles positioning devices, benchmarking on customer access modalities, analysis of ICT tools for data collection and harmonisation and technical, economical and organisational analysis. The activities described concerned technical, organisational and economic activities and the main aspects of a mobility Agency.

Agency concept

The core objective and focus of IMoSPro is the integration of infomobility services with an advanced management IT platform to support operation of the Agency starting from similar experience in other fields (Ambrosino et al, 2005). Overall, the main innovative aspect of IMoSPro is the possibility of integration of several infomobility services about public transport. Figure 3.40 provides a schematic illustration of the basic concept of Agency where is possible to underline 4 different levels:

- core;
- information;
- users; and
- channels.

In particular the core is defined by an integrated database constructed through standard Transmodel that contains data about public transit operators. Available infomobility services (pre trip, en route and in-vehicle) are: list of public transport operators, timetable, fares, trip planning, bus stop waiting time, etc. Potential users are: single travellers and private citizens both for the public transport and the goods transport, council Boards, Municipality, Provinces, the Autonomous Sardinia Regional Board, transport sector operator, transport service operators and goods transport operators and any others that work in the area, brokers, forwarding agents, lorry carriers. Finally, these services could be available through some channels such as: portable devices (i.e. land-line phone and wireless devices PDA, cellular line, etc.), non-interactive displays (i.e. electronic boards), interactive wayside devices: (i.e. kiosk.) and Internet and e-mail services (i.e. web portal, etc.).

This concept presents a back-end and a front-end interface. The back-end is represented by public agencies that supply transport network data. Data are converted into

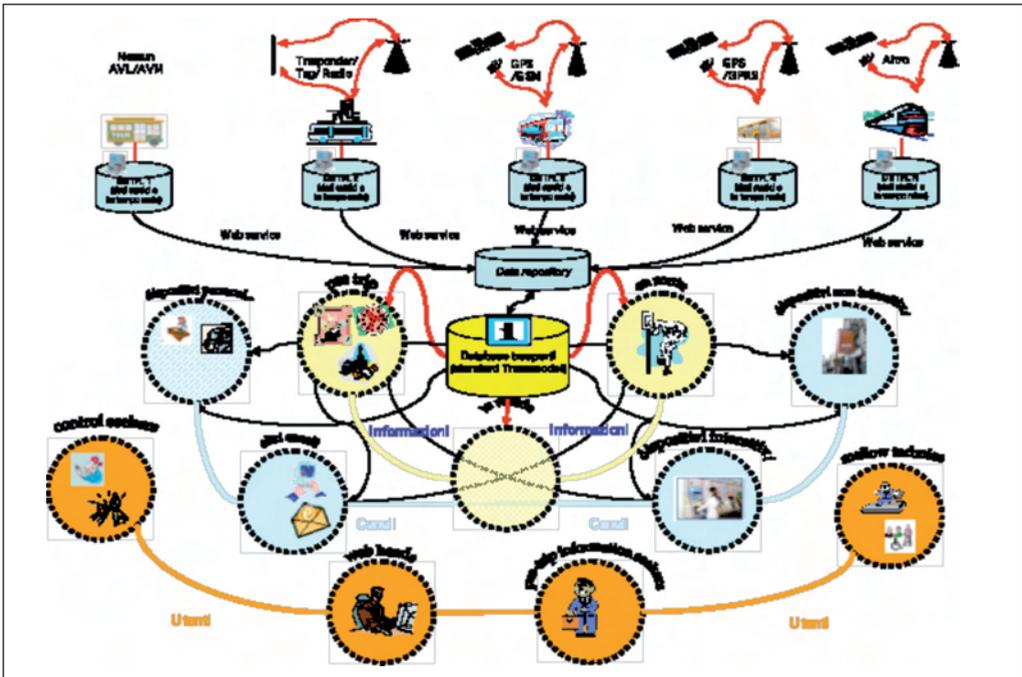


Figure 3.40: Agency concept (Barabino, 2007)

information with an internal process and showed at users using channels defined: this presents the front-end area.

Technical and Organizational analysis

Technical and organizational analysis describes the services provided by the Mobility Agency from a functional, technical and organisational point of view (AAVV, 2005b). A sufficiently broad and generic conceptual model was set-up, in order to ensure the highest possible flexibility. The web portal and Contact Centre functional requisites were designed and an implementation hypothesis for the Agency Information System presented, based on Web Services. With this type of organisation, the multi-service Agency will be able to answer to the continuous requirements of the travellers who require more and more detailed information. This Agency answers to the requirements of the relative companies to the necessity to find a shared and preferential channel in order to disclose their services.

Financial and Economic Analysis

A financial analysis (Costs Revenues Analysis) and economic analysis (Benefits Costs Analysis) were completed (AAVV, 2005c). The first (CRA) is important for a private investor while the BCA is for a Public investor. Analyses conducted (intentionally with

caution) have produced interesting results in terms of feasibility not only from the economic point but also from financial justification of the choice. In CRA the following costs are calculated: Agency rooms cost, data centre cost, contact centre cost, peripheral (on ground) devices cost and general cost. The total estimated cost is higher than €5,000,000 but it is possible to divide it in peripheral devices (€4,660,000) and other elements (€639,200). Estimated revenues comprise: in-bound traffic to the Agency, user SMS, Web portal, information supplying via portable devices (PDA) and advertising. The total annual revenues are €425,289 (10th year) while annual maintenance and management costs are €302,160 (10th year). In BCA several benefits (direct and indirect) have been estimated such as: time saving for public and private users, less cost of system use, fuel saving and reduction of external cost.

Results show that VAN (6% and 7%) is positive and SIR is very good.

Pilot project results

Because financial analysis shows high investment costs a demonstration scenario was set as shown in Figure 3.41.

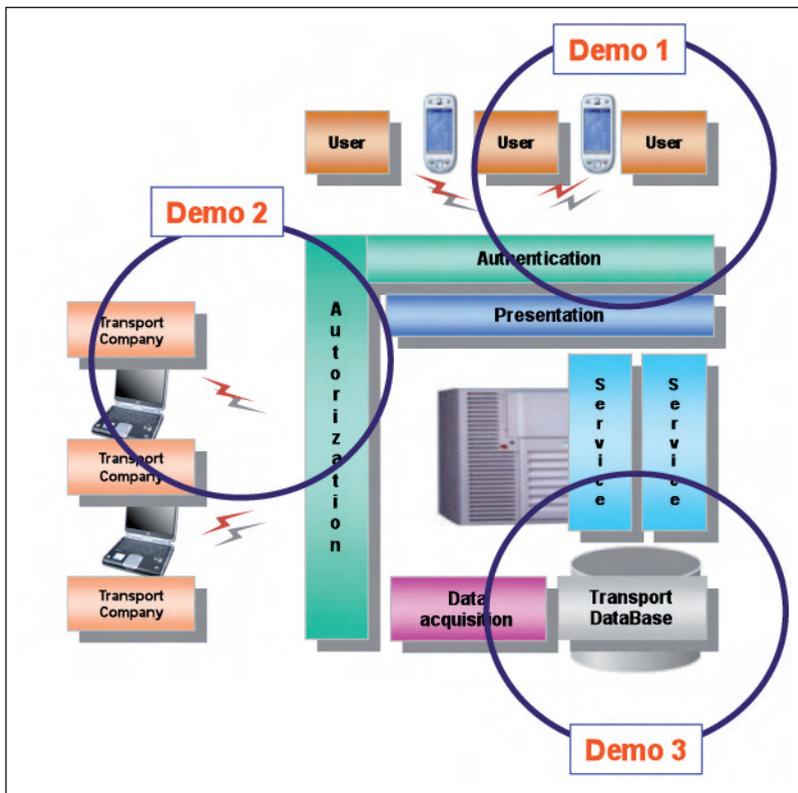


Figure 3.41: Demonstration scenario

The demonstration scenario is based on shared resources used in different ways by three applications. In particular demo 1 is a tool that supplies customized information about the positioning of the fleet via PDA with GIS application; demo 2 is a tool that supplies general information about the service to customers simulating intelligent rods and totems; and demo 3 is a tool that collects and manages data from different transport fleet making available some information on the web. The following paragraphs describe the demos developed.

DEMO 1: Customized information supplier

This is the development software of application for PDA using a commercial GIS to display vehicles position (AAVV, 2005d). The PDA uses a tom-tom navigator and icon displays to represent the position of a number of CTM vehicles in the Cagliari area at a given moment (Figure 3.42).



Figure 3.42: Example of developed tool

The system works on a slight delay to allow the data to pass through the GPS connection from the vehicle to the operating centre and then from the centre to the PDA. The tool InfoCagliari is based on a SW Pocket Driver platform and it is able to display the Cagliari buses positions onto a map. Testing has shown that possible improvements could be the visualisation of the route that each particular line takes for those who do not know the Cagliari transport service. This software could also be used with other output devices, for example via Internet.

138 Figure 3.43 provides results of this tool.

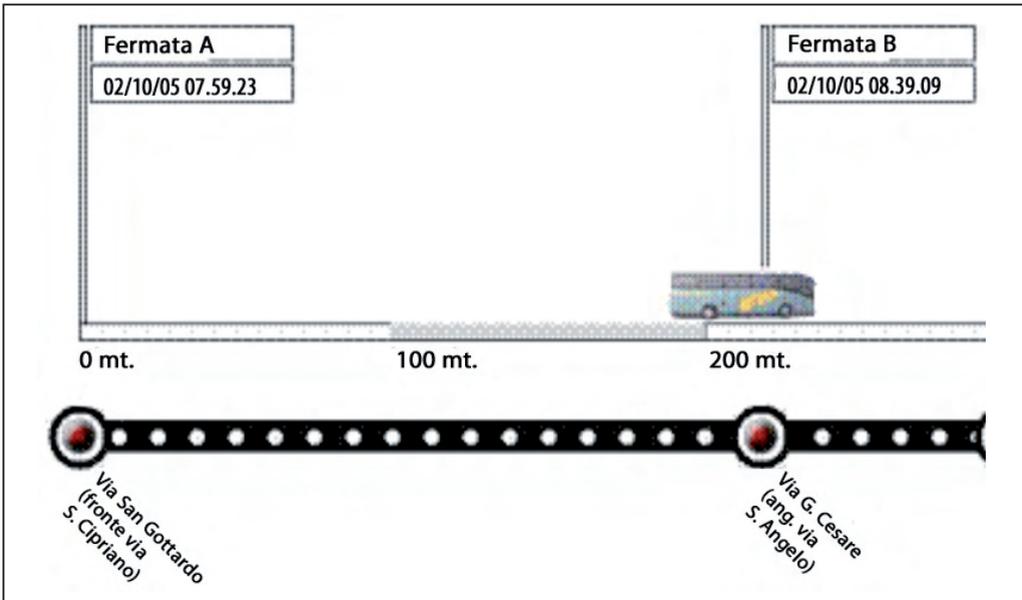


Figure 3.43: Example of developed tool

DEMO 2: General information supplier

A program to be installed on the transport company server was projected and developed (AAVV, 2006). The software receives data from vehicles equipped with telematics systems and stores all the data in a data base. A second software program analyses the data stored in order to extract and elaborate useful information to be supplied to customers or to transport company employees (i.e. expected time to arrive at a given bus stop).

DEMO 3: Different fleet data collection and management

This is the development of the web portal (www.agata-cagliari.eu) which is divided into a number of applications such as:

- travel planner service
- virtual bus stop
- vehicle positioning

The travel planner service (Figure 3.44) offers users a direct or indirect route from the chosen starting point to chosen destination. The software is based on a database with coding only on bus stops. This plan is simple but could be improved by coding roads in a chosen area so that the user can insert the road where they are and discover whether there is a bus stop or not as well as where it is. The virtual bus stop (Figure 3.45) allows users to see the services and equipment provided at a given bus stop, i.e. information on board, seating, shelter and the various transport operators operating there (Figure 3.46).

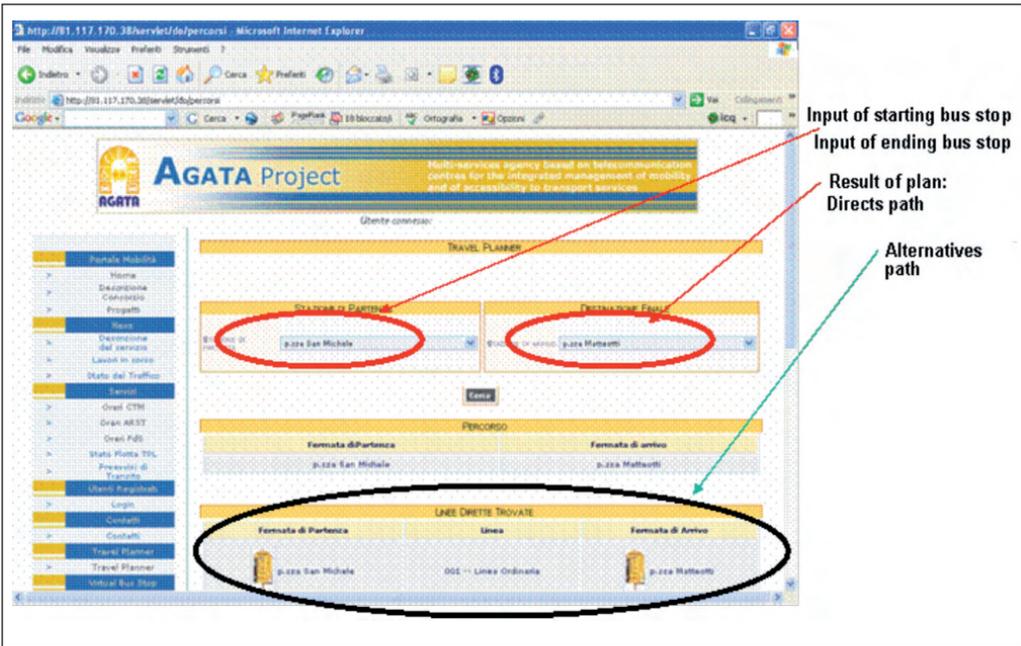
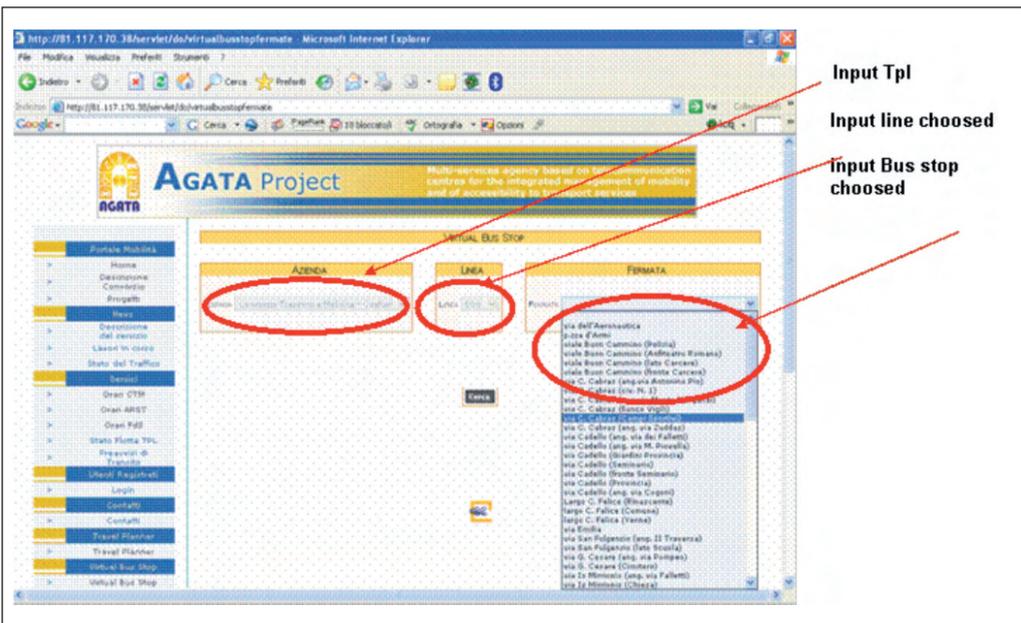


Figure 3.44: Travel planner service



140 Figure 3.45: Virtual Bus Stop

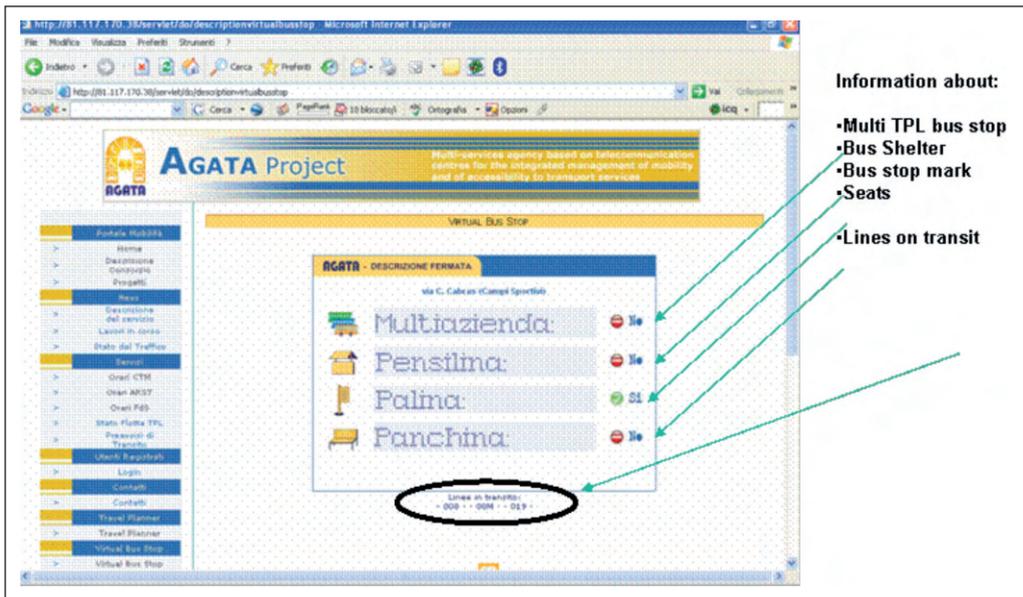


Figure 3.46: Virtual Bus Stop Results

The vehicle positioning component is a similar service as shown on the PDA. However, it is not visual and provides textual information. The position of the bus is currently shown in latitude and longitude but this should be improved with name of street.

3.9.5 Conclusions

Experience carried out with the POR Project and AGATA in the Sardinia context shows the importance of telematics technology to manage the public and private traffic and to improve the information.

The POR project aims to create an integrated telematics platform composed of 10 sub-systems in order to manage private and public transport. The development of this project was carried out through 2 phases: an experimental and a realization phase. In order to reduce risks the realization phase has been organized in four contracts which are on-going. Results obtained show high complexity in order to integrate every sub-system but a strategic importance to traffic e-government.

The IMoSPro project tries to underline a prototype of an Infomobility Agency which integrates several information services about a public transport company and makes them available both with innovative and flexible instruments and via Internet. The development of this project was carried out through a local site analysis, a feasibility study and a realization of 3 demonstrators. Results obtained show different ways of improvement towards the creation of a multi-services Agency in order to improve the quality of life of users.

3.10 Infomobility and Bus Rapid Transit corridors: the experience of Quito

A. Viteri, H. Nuñez, G. Freile, G. Ambrosino, S. Gini

3.10.1 Introduction

This section is dedicated to the description of the experience carried out by Quito Municipality, in Ecuador, in setting an Integrated Infomobility and Payment system on the Bus Rapid Corridor named “TROLEBUS” which forms one of the 5 BRT corridors of the Metro-Q transport system. It is structured as follows: following an introduction to the traffic context in the Quito Metropolitan District (QMD) there is a detailed description of the introduction of BRT in Quito with a special focus on the ITS applications adopted on the “TROLEBUS” corridor.

3.10.2 Quito Metropolitan District: context

Quito, the capital of Ecuador, is located in the north-east of South America standing at an altitude of 2,800 meters. Quito Metropolitan area, a canton in the Pichincha, province covers a surface of 12,000 km² and has been developing transversally as the area suitable for building is limited in the west by volcanoes and in the east by mountains. In 2005 the population was estimated at about 2,500,000 (82% living in the urban area) but it is expected to grow to 3,300,000 inhabitants by 2021.

Mobility Demand

Quito Metropolitan District (QMD) like several of the largest metropolitan areas in the world, especially those belonging to the developed countries, must face relevant problems concerning mobility services accessibility, traffic congestion and the environmental situation (involving amongst others, high travelling time, costs and efficiency of public transport operation, accessibility from peripheral areas, high pollution levels, etc.). The impacts of these problems, if not controlled, could become worse in the near future due to the increasing private car rate that will be expected to double by 2021 (up to 200 vehicles every 1,000 inhabitants). By 2021 the overall amount of cars circulating in Quito will be expected to be 660,000, five times greater than the current level and the modal shift will be 40-60 (private-public vehicles).

Although car ownership and use are increasing, the public transport services are still the mode most used by citizens (over 70% of Quito citizens). In this context one of the main objectives of the Quito Municipality policy for mobility and sustainability measures is the enhancement and extension (in timing and space terms) of the overall public transport services implemented as the most appropriate answer to the increase of population, to different citizens' mobility needs and to the environmental situation.

Mobility and Transport Measures

142 The Municipality of Quito (through the Metropolitan Department of Transport, DMT,

and EMMPOQ, the Metropolitan Department of Mobility and Public Works) designed a reference Mobility Transport Act (MTA) as an *integrated and dynamic plan* for 2020 with the basic idea that a city is a well organized social and territorial unit able to guarantee



Figure 3.47: Vehicles and stop infrastructure ("Ecovia" corridor)



Figure 3.48: Vehicles and stop infrastructure ("Trolebus" corridor)



Figure 3.49: Bus stop of the Corridor "Ecovia"



Figure 3.50(a) and (b): Vehicles and stops of the Corridor "Centrale Norte"

all citizens the right to the mobility by the access and use of an efficient, affordable, safe and sustainable transport system and services. The measures defined in the MTA for developing the transport system offer have been identified through the involvement of all the institutional, social and operational actors and stakeholders.

One of the objectives of the MTA identifies the realization and extension of Bus Rapid Transit (BRT) corridors with related feeder services as the key tool for expanding and enhancing the overall mobility and transport system in Quito.

The main measures identified in the MTA can be summarized as follows:

- Setting up a normative framework for public transport operation based on clear rules for co-operation among private and public sectors/operators in order to manage the contract services and guaranteeing high performance levels;
- Design, implement and improve the bus network/system including:
 - 5 BRT integrated corridors with high capacity transport based on dedicated and priority infrastructure;
 - feeder services and the transversal connection services improving the accessibility of the inner centre from the neighbouring areas/towns of QMD;
- Definition of an integrated tariffs policy in order to increase the coverage of public transport, to foster the accessibility and integration of the different services;
- Implementation of an Information Communication system for managing public transport and traffic co-ordination;
- Implementation of user information systems to be installed on the buses and at the bus terminal/stop;
- Implementation of an integrated payment system and takings/revenues redistribution among the transport operators operating on the same network as the MetroQ system.

At an organizational level Quito Municipality established a specific entity in 2008: EMMPOQ (Metropolitan Department of Mobility and Public Works) to carry out the co-ordination of the above measures and the management, control and monitoring of the contractual obligations of the transport executives and operators.

3.10.3 Public Transport

The overall public transport network is composed of 180 lines operated by about 3,300 buses. The organization of the public transport services is based on the operation of “high-frequency and high capacity” BRT corridors serving the most important areas of QMD from north to south. The overall accessibility to the 5 BRT corridors is provided by feeder lines (from west to east). These feeder lines are classified as: services connecting peripheral districts with BRT corridors, connecting services among the different BRT corridors, and services connecting other destinations using part of the BRT corridors.

The Bus Rapid Transit corridors are dedicated only to the public transport vehicles (without any permission to be used by other city service cars) operated by friendly and clean 18 metre vehicles, with equipped bus stop infrastructure (500/800 meters apart from each other) and bus priority at specific and strategic junctions. At present three corridors are operated: “green line” (named “Trolebus”), “red line” (named “Ecovia”) and “blue line” (named “Corridor Central Norte”); another two are already realized and will start running in the near future.

3.10.4 BRT Corridors

BRT Corridors currently operated

The “green line” BRT (named “TroleBus”) is the corridor from “Estacion Norte – La Y” terminal to “Moran Valverde” terminal. This corridor is the first to be operated in Quito, since December 1995 (one of the first implementations in South America together with the BRT realized in Curitiba - Brazil). The corridor with an initial length of 11.2 Km was later extended to the South to the actual length of 16.4 Km in 2000. The TroleBus corridor is operated by 113 vehicles over 6 different circuits (defined as a limited part of the overall corridor). The service frequency is very high (during the peak hours the frequency is up to 2-3 minutes). The number of daily trips is about 267,000. 15 feeder lines operated by 91 buses interconnect the Trolebus corridor to other destinations (for a total network of about 101 Km). One of the most used feeder lines (La Y – Carapungo) presents about 4,000 daily passengers. Feeder lines have been subcontracted by CTQ (the Public Transport Company of the Quito Municipality) to private transport companies that operate them according to a specific service contract. This corridor is planned to be extended from “Moran Valverde” terminal to “Quitumbe” terminal. The completion of the new infrastructure ended in 2008.

The “red line” (named “Ecovia”) is a BRT corridor from “Marín” terminal to “Rico Coca” terminal which started operation in 2003. The corridor (9.4 Km) is operated by 42 articulated vehicles over a single circuit. The number of daily passengers is about 123,000. Eight feeder services that interconnect the Ecovia corridor to other destinations (for a total network of about 118 Km) are operated by 37 buses with 15,500 daily trips. This corridor is planned to be extended on the southern side from “El Recreo” terminal to “Quitumbe” terminal.

The “blue line” (named “Corredor Central Norte”) is a BRT corridor from “Seminario Mayor” terminal (in the inner centre of Quito) to “Ofelia” terminal (in the north part of the city) which started in operation in 2004. The corridor length is about 16.4 Km and is operated by 74 articulated vehicles; feeder services interconnecting the “Corridor Central Norte” to other destinations are operated by 112 buses. This corridor covers a potential demand area of 700,000 inhabitants with 480,000 average planned trips each day. At the moment about 60% of the overall project has been implemented. The total

investment that the Municipality carried out for the infrastructure (routes, shutdowns, terminals, signalling) was \$22 million (approx. \$1.5 million per kilometre). The investment of the operators (an association of private transport executives) was \$16 million for the purchase of the articulated buses and \$21 million for the conventional buses. Aspects of the current BRT corridors are shown in Figures 3.47 - 3.50.

Table 3.4 summarizes the trips per day on the overall public transport system.

TYPE OF SERVICES	TRIPS/DAY	%
Corridor "Trolebus"	267.000	15
Corridor "Ecovia"	123.000	6
Corridor "Central Norte"	140.000	7
Feeder services and other bus lines	1.384.000	72
TOTAL	1.914.000	100

Table 3.4: Daily trips on the public transport system in Quito

The Future BRT Corridors

Another corridor (named "Corredor Mariscal Sucre") will connect "Norte Carretas - Miraflores" and "Miraflores - Quitumbe" with about 40,000 planned daily passengers. The last corridor is named "Metropolitans" including the corridor Quito-Tumbaco-Quinche and the valley of Chillos. The first one will involve 5 operators and a fleet of 196 buses for a planned demand of 55,000 passengers/day. With regards to the corridor Quito-Valley of the Chillos the project involves 12 operators with a fleet of 433 buses. The corridor will offer a main circuit from Quito to San Rafael (15.2 Km) with a variant circuit to Conocoto and it will involve a planned demand of 60,000 passengers/day.

Figure 3.51 depicts the current and planned BRT network.

Integrated Fare System

As the different corridors were implemented separately, the Municipality of Quito decided to promote the integration of the fares between the BRT system and feeder services. As a first step the integration has been carried out at single BRT-feeder level (TROLEBUS BRT) but the integration to the other corridors operated is in progress. In the "Trolebus corridor" two tariffs are available (established in January 2003): the normal tariff is \$0.25 and the reduced tariff for disabled people, elderly people and students under 18 years is \$0.12. One single trip ticket allows every trip in the BRT corridor and one trip from a terminal (interconnection point of BRT corridor) to stops of feeder lines. In "Corredor Nordoriental Ecovia" there is a fare structure similar to the previous one. In the "Corredor Central Norte" the tariffs are based on travelled distance. In the public transport network blind people can travel free of charge.

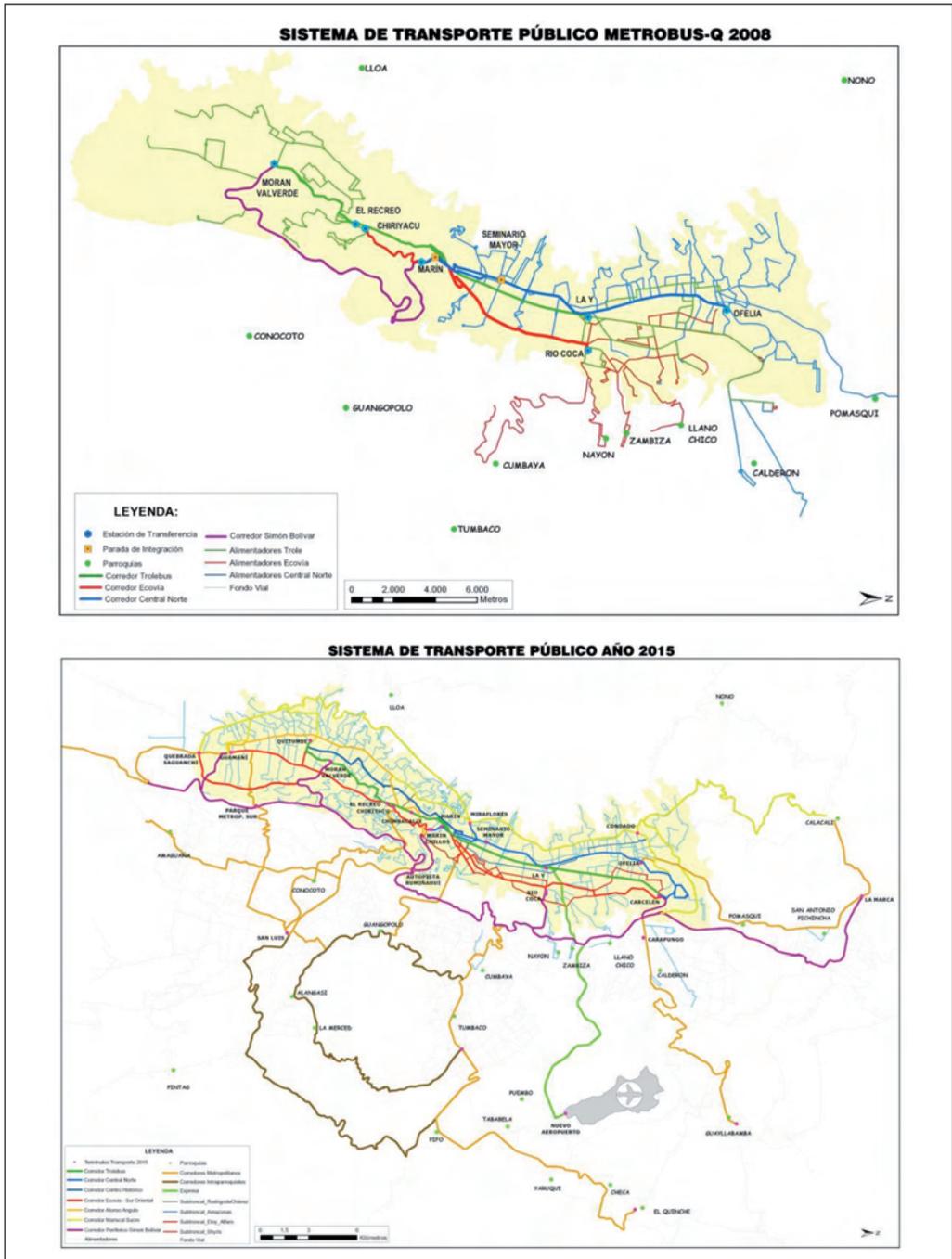


Figure 3.51: Network of public transport services of MetroBus-Q (year 2008 vs year 2015)

3.10.5 ITS Systems in the “TROLEBUS” Corridor

To face the mobility demand Quito Municipality acted not only on the infrastructure side but also by using Information Communication Technologies (ICT) in order to operate and manage BRT corridors daily. In particular the TROLEBUS corridor was chosen as the pilot experience for future extension to the other corridors taking into account the different operation modalities (i.e. trolley/articulated buses) and responsibilities (i.e. public company/private operators). The ITS systems designed, contracted, implemented and integrated for the TROLEBUS corridor have been the following ones:

- Electronic Payment System supporting the interoperability between the corridor and its feeder lines based on the integration of the related fare system;
- Fleet Monitoring System in order to support the operation and the control of TROLEBUS corridor and the related feeder lines;
- Users Information System providing on-board “next stop” announcement and “pre-trip” information at bus stops and terminals;
- Video Surveillance System installed at TROLEBUS terminal and stops.

The Objectives for the introduction of the Systems

(a) Integrated Payment System

The previous system was based on automatic access barriers (accepting defined typologies of coins) and a manual procedure of selling “paper” tickets (for reduced fare). The change of the coins was carried out manually at specific desk points.

The objectives related to the introduction of electronic payment system are the following:

- Renew the validators and access barriers;
- Improve the quality of the transport service reducing the access time;
- Obtain the daily data about the users accessing the transport system automatically;
- Generate the statistics about the origin-destination matrix;
- Make available automatic procedure for registration of events that occur in the terminal/stops.

As the previous payment system was mainly based on a relevant use of employees for controlling and managing the ticketing service, another objective (even if not the most important) is the reduction of the number of persons involved in the fare process management.

(b) Fleet Monitoring System

Before the system implementation the control of the operation of the service was carried out manually through the use of daily tables. In each terminal there was a responsible person in charge of checking the departure time of the vehicles according to the table of the scheduling times. Furthermore there were other people in charge of checking the

timing of the vehicles standing on the road. The information collected on the road was used to tune the correct interval between the vehicles and regulate the departure time of them. These actions were carried out by a Control Centre (managed manually) in charge of the identification of the interventions that could be necessary in case of delays, absence of a vehicle, traffic congestion, etc. The information required by the Control Centre in order to put into practice the appropriate corrective actions was transmitted via radio (to those responsible on the road or to the drivers). This procedure was affected by errors and incorrectness, above all for the monitoring of feeder services. Furthermore the communication network was not updated to the state-of-art resulting in inefficient performances.

Before the implementation of ITS systems, user information was not provided on board. Information on vehicle timetables was provided at the terminal (without the real-time updating during the operation of the service).

In this context the objectives of the fleet monitoring system are the followings:

- Carry out the monitoring of the fleet partially using automatic procedures;
- Implement an automatic system to collect performance results on the operation of the service that can effectively support the planning activity;
- Make available real-time information on the operation of feeder services;
- Implement an innovative users' information system (on board and at TROLEBUS terminal and stops).

(c) Video Surveillance System

The main objective of the implementation of the video surveillance system has been to increase the safety of users and workers (due to the increased number of thefts) and provide support to the operators working at stops in a more efficient way. The surveillance aims to carry out the real-time monitoring of corridor stops (to be managed by the Control Centre) and the registration and storing of images (for later control of crimes and vandalism events).

The Implementation of ITS Systems

(a) Architecture of the System

The architecture of the system is shown in Figure 3.52.

As shown in the figure the architecture of the system includes the following components (for each component the main functionalities are listed).

Electronic Payment System:

- Rechargeable smart card (contactless, RFID technology, MIFARE interface, ISO 14443A compatibility);
- One trip tokens (contactless, RFID technology, MIFARE interface, ISO 14443A compatibility);

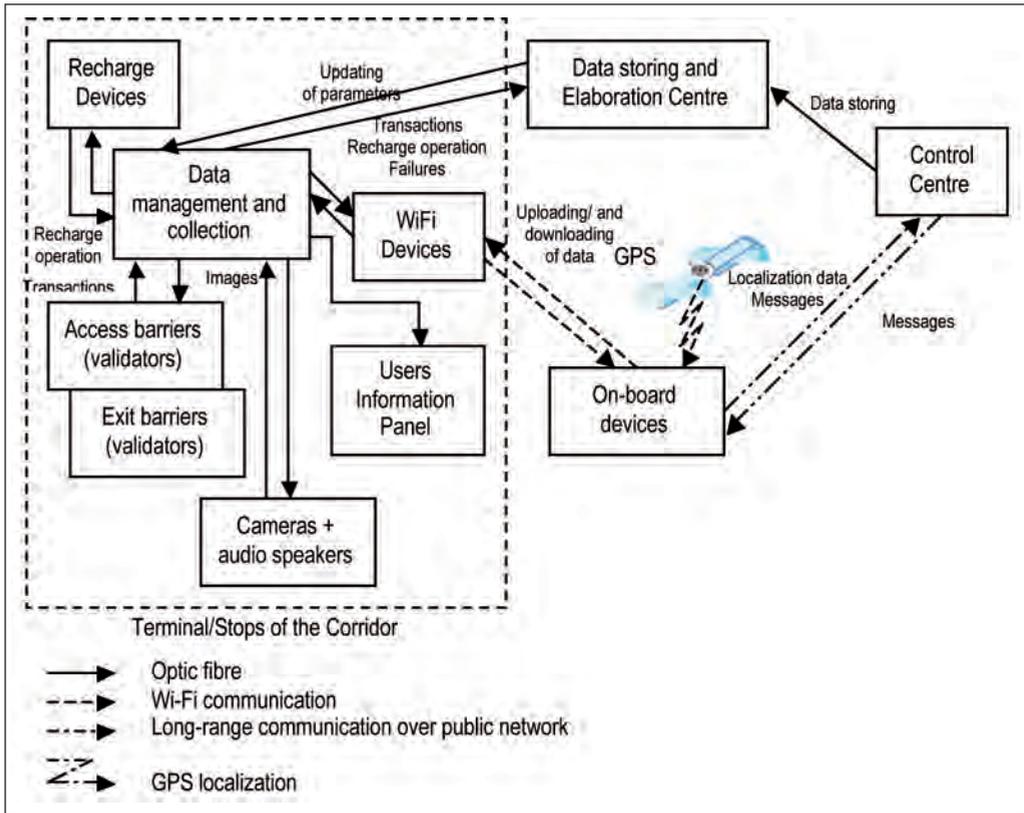


Figure 3.52: Architecture of the system

- Data storing and elaboration centre (DEC):
 - Collection of data from devices installed in the terminal/stops of the corridor and on-board (transactions and diagnostics of failures, etc.);
 - Data process and elaboration of statistical reports;
 - Definition of the total amount of daily access in the transport network (BRT corridor + feeder services) and total income;
 - Export of statistical report;
 - Management and transmission of the configuration parameters of the devices installed in the terminal/stops of the corridor and on-board;
 - Import of data related to network and service operation;
 - Access administration;
 - Back up;
- Devices for data management and collection at the terminals and stops (data communication to/from DEC, etc.):

- Collection of data from devices installed in the terminal/stops of the corridor and on-board (transactions and diagnostics of failures, etc.);
- Management and transmission of configuration parameters installed in the terminal/stops of the corridor;
- Recharge devices:
 - Transmission of data related to the recharge operations;
 - Updating of configuration parameters transmitted by the data management and collection devices installed in the terminal/stops of the corridor;
 - Transmission of failure diagnostics;
 - Printing of the receipts;
- Validators installed at access barriers for all users (including disabled):
 - Control of the access of users (management of the access barriers);
 - Validation of the smart card;
 - Process and storage of the tokens;
 - Visualization of the information for users (result of the validation, cost of the trip, amount of money charged in the smart card, etc.);
 - Updating of configuration parameters transmitted by the data management and collection devices installed in the terminal/stops of the corridor;
 - Transmission of failure diagnostics;
- Validators installed at exits of stops:
 - Validation to get data for O/D trips analysis;
- On-board validators (installed on the vehicles operating feeder lines):
 - Control of the access of users (management of the counter accessing gate);
 - Validation of the smart card;
 - Visualization of the information for the users (result of the validation, cost of the trip, amount of money charged in the smart card, etc.);
 - Updating of configuration parameters transmitted by the data management and collection devices installed in the terminal/stops of the corridor;
 - Transmission of failure diagnostics;

Fleet Monitoring System:

- Control Centre:
 - Monitoring of the vehicles;
 - Visualization of supporting information;
 - Transmission/reception of the messages;
 - Data processing and elaboration of statistical reports on service operation;
 - Export of reports;

- On-board devices:
 - On-board control unit
 - Management of all on-board devices;
 - Updating of configuration parameters transmitted by the data management and collection devices installed in the terminal/stops of the corridor;
 - Transmission of failure diagnostics;
 - Interface module;
 - Amplificatory module;
 - Terminal for drivers
 - Visualization of the information related to the service;
 - Time difference of the previous and following vehicles;
 - Sensors to get open/close signals of the door:
 - Video cameras;

Users Information System:

- Users information “on-board” through panel + audio speaker:
 - Visualization of next stop;
 - Announcement of next stop;
- Users information at BRT terminal and stops:
 - “Real-time” information on the time of arrival (at stops) and departure (at terminals) of the buses;
 - Visualization of messages for condition of irregular service (traffic congestion, incidents, strike, etc.);

CCTV (Video Surveillance) System:

- Monitoring Centre:
 - Visualization of images transmitted by video cameras (real-time);
 - Visualization of images (batch procedure, on the basis of criminal events);
- Cameras:
 - Images
- Audio speaker and emergency alarm button
 - Real-time communication between BRT terminal/stops and the Control Centre;

Communication Systems:

- Optic fibre between Data storing/Elaboration Centre and Data Management/Collection devices installed in the terminal/stops of the corridors;
- Wi-Fi communication for data transmission to/from the vehicles (uploading and downloading of tariff structure, network and service data);

- Long-range communication for data transmission to/from the vehicles (messages, data for localization, etc.).

Figure 3.53 shows the architecture of on-board devices (the picture relates to a bus typology operating in a feeder service).

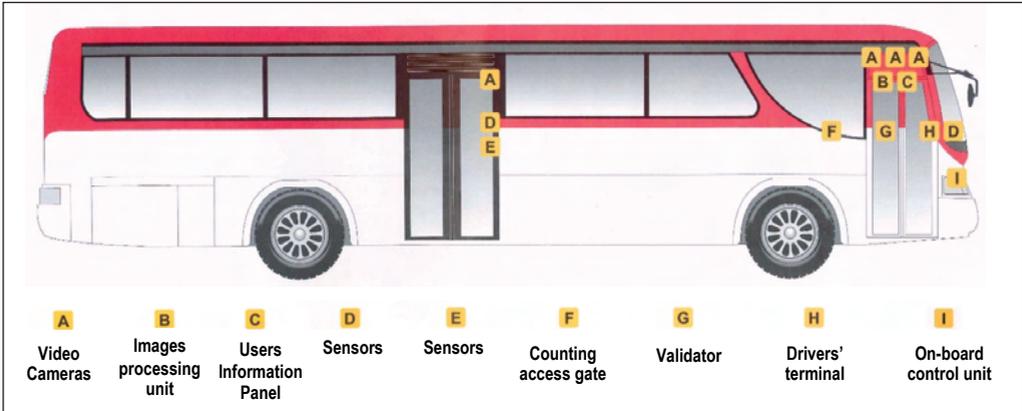


Figure 3.53: Architecture of on-board devices

(b) The Electronic Payment Systems

After the implementation of the electronic payment system a smart card is used to access the transport system. If the users have no smart card, they must use the tokens (single trip tickets). Smart cards must be bought at a specific desk point that has been activated in the most important terminal of the corridor. Recharge operations of the smart cards can be carried out at every terminals/stops of the corridors where it is possible to buy



Figure 3.54: Information campaign to promote the launch of the electronic payment system

the tokens too. Smart card and tokens are validated on the validators installed at bus stops/terminals (BRT corridor) and on-board (feeder services, counting barriers are still in operation).

The data storing and elaboration centre carry out the process of data (transactions, recharge operations) in order to provide the statistical reports (number of passengers, number of recharge operation, etc.) filtered over time (daily, etc.). The total number of users (per each day) and the total amount of transactions registered by the system are reported and compared to the money collected and accounted (from the selling point). The procedure of collecting and accounting for the money is still the same after the implementation of the electronic payment system. The people collecting the money and used tokens (from the access barriers) are employed by the IT provider but the co-ordinator of each team is a CTQ worker monitoring the activities and checking the final accounting of figures.

(c) The Fleet Monitoring and Users Information System

The control centre is operated by CTQ personnel. The data collected are suitable to perform the verification of the service quality of the sub-contracting private transport companies and to support the management and regulation of bus frequency on the BRT corridor (currently mainly carried out by CTQ personnel working on the road”).

Electronic panels have been installed to provide “real-time information” on the arrival/ departure times of each vehicle. The panels have been installed at the terminal and in the corridor’s bus stops. The information provided is based on “pre-defined” timetables; modifications on the predefined timetable can be updated through the intervention of CTQ operators. On-board information based on the visualization and the announcement of the following stops is also provided.

(d) The Video Surveillance System

The video-surveillance control system is based on video cameras installed in the stops and terminal platform connected to a monitoring centre (located in AVM Control Centre). This contributes to increase the safety of users and CTQ personnel. The cameras carry out the real-time monitoring of the stop area. The images are reproduced at the monitoring centre and recorded by the cameras. An alarm button is installed at stops: by pressing the button the alarm is transmitted to the monitoring centre and the operator is immediately warned and can watch what happens at the stop/terminal commanding the installed cameras remotely. Through audio speakers the operator has the possibility to communicate with the stop. During the night the cameras transmit the images that have been recorded to the monitoring centre. At the monitoring centre it is possible to carry out search operations (based on time, events, etc.).

Cameras have also been installed on the vehicles operating feeder lines and images are stored on the on-board recorder. The images can be transferred manually and reviewed in the Control Centre.



Figure 3.55: Control Centre for fleet monitoring



Figure 3.56: Users information at corridor's terminal



Figure 3.57: Monitoring Centre: images from the cameras



Figure 3.58: Validators at access barriers (corridor Terminal)

3.10.6 ITS Systems for Traffic Management

The objective of this system is to improve the circulation of the vehicles, decrease the number of accidents, and reduce the emissions produced by the vehicles and the overall level of congestion. It is widely demonstrated that a relevant increase of the road capacity can be achieved through a higher efficiency in the management and co-ordination of traffic lights.

In Quito the management of the traffic lights has been performed at two separate institutional level:

- The Municipality through EMSAT;
- The National Police though DNT (National District for Traffic and Transport).

EMSAT manages about 350 intersections of which 266 are centralized. These are 3-generation devices based on responsive demand control strategies. The National Police manages 322 intersections of which 49 are located in the Quito Metropolitan Area. These

are 1-generation or 2-generation traffic light junction devices which are not centralized. Indeed the two systems are operated in “stand-alone” modality without any interactions in the street or centre to centre. Being two independent systems based on different technology roads and corridors with both kinds of intersections they cannot be regulated efficiently. This leads a negative impact on public transport operation. This consideration added to others mainly related to the limits and obsolescence of technologies and has led the Municipality to carry out the feasibility study for the planning and tendering of an integrated centralized management system for the overall traffic light network.

3.11 The role and perspectives of the large-scale Flexible Transport Agency in the management of public transport in urban areas

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3.11.1 Introduction

Flexible Transport Services (FTS) have proved to be an advantageous solution in integrating and complementing the provision of conventional public transport services in order to reduce pollution and congestion whilst increasing the social cohesion and encouraging sustainable economic growth especially in urban and metropolitan areas. The European Regional Co-operation Programme INTERREG IVC recently launched the FLIPPER project to address a key factor of eco-sustainable and competitive development and social cohesion of European areas and Regions through the investigation, exchange of experience, transfer of good practice and profitable co-operation on FTS in relation to mobility in cities, rural areas and mid-sized towns. This section outlines the role which FTS could play in the urban and metropolitan area by (a) integrating and expanding the overall collective transport offer; and (b) complementing the other transport modes in a perspective of “co-modality” as pursued by the European Commission from the Lisbon Agenda (see section 2.2). The concept of FTS and in particular of DRT is provided with the presentation of the FLIPPER project objectives and approach. The main part of the paper focuses on the concept of “Large-Scale FTS Agency” as an unique co-ordination centre for managing different flexible transport services in urban areas (planning, operation, integration), in order to improve the overall public transport service offer to make urban areas more sustainable and less congested.

3.11.2 The current situation in European cities: transport policy and public transport

European urban and metropolitan areas, as elsewhere in the world, are facing heavy levels of traffic congestion and related environmental degradation (noise, pollution, vibration, etc.) due to the high rate of private car use and many other demands acting on the same

network (public transport services, goods distribution, waste collection services, tourist buses, etc.). Another aspect of this generalised degradation is the continuous strong decrease in public transport usage due not only to competition from the private car but also to the rigidity of the public transport services offer which remains based on fixed lines and timetables, while the economic aspects and different life styles in European cities provoke an erratic and non-homogeneous mobility demand.

From the Lisbon Agenda at transport policy level, the European Commission has promoted the concept of *co-modality* as a way to guarantee the growth of competitiveness in Europe in a sustainable manner. The White Paper “European Transport Policy for 2010: time to decide” (EC, 2001) states the need to utilise integrated transport modalities and the mid-term review of the White Paper “Keep Europe moving” (EC, 2006) indicated the optimization of each transport mode as the way to achieve a clean and efficient transport system: in this way we *move from the notion of competition between transport modalities to the concept of complementarity*. From this perspective the EU recognised that the co-ordination of the different actors is mandatory in order to guarantee the quality and integration of the overall transport chain as a whole. This is still more mandatory for the European cities and metropolitan areas where there is an evident lack of co-ordination among the various public and private entities – car traffic, public transport services, freight and goods transport operators, emergency services, etc. – who with different aims, roles and responsibilities share the same road infrastructure and generate negative impacts whose cumulative effect is very visible in terms of environmental quality and sustainability of city life.

In Europe, many constraints – ranging from the urban structures and environmental issues to regulations, costs of road infrastructure and community budget limits – lead cities and local authorities to look for Information Communication Technologies (ICT) tools and systems as a fast and efficient response to a number of complex and compelling issues, including traffic congestion and pollution, poor accessibility and low usage of public transport, lack of sustainable mobility schemes for increasing service efficiency (not least the logistics services).

The relevance of ICT systems (also referred to as Intelligent Transport Systems¹) has been recognised with many initiatives during the last 20 years and recently with a specific Recommendation, the “ITS Action Plan” issued by the European Commission (EC, 2008) where the ITS applications have been identified as the key element contributing to this efficient co-ordination of the overall transport chain: in urban and metropolitan areas it means to realise an *Integrated Mobility Management and Control System*.

At the same time the public transport approach and offer in urban and metropolitan areas is evolving in this direction of co-operating with the other modes under an integrated

1 <http://ec.europa.eu/transport/its>

“ICT umbrella” for achieving a clean and efficient transport system by the realization/ implementation of relevant actions, which include at least the following measures:

- a) dedicated collective transport corridors with priority and high frequency (from Busway to Bus Rapid Transit (BRT) concept or Tramway);
- b) feeder services to the main terminal or stops of the public transport network/corridors;
- c) connecting services among the different corridors;
- d) development of innovative models and services for the erratic urban mobility and to complement the overall public transport offer and the other modalities (parking areas, etc.);
- e) usage of clean and eco-compatible fleets.

It is easy to recognise that the above element d) involves the provision of Flexible Transport services (FTS) and in particular of the Demand Responsive Transport services (DRTs), where European cities, authorities and transport operators have developed an huge experience and many real applications (Ambrosino et al, 2009; Ambrosino, et al 2005). This experience with DRTs has been consolidated and improved over the last 5-10 year in some European projects (IST-FAMS, INTERREG IIIB AGATA, LIFE-CEDM, Regione-Toscana CLOVER, etc.) and in some cities (Livorno, Firenze, Genova in Italy) evolving to the Flexible Mobility Agency concept based on web services for managing and co-ordinating different operators and transport service typologies (B2B services), allowing a large interface of options and possibilities to the users (B2C services) and the interactions and dialogue among the different authorities and entities involved in the control of transport services (B2A services).

3.11.3 Urban passenger transport and FTS

During the last ten years many DRT applications have shown important advantages and benefits in several European cities and regions and in many European co-financed Framework Programme IV, V, VI projects (e.g. SAMPO, SAMPLUS, VIRGIL, SIPTS, INVETE, FAMS, CONNECT) and in Inter-regional Co-operation Programme 2000-2006 projects (e.g. MEROPE and AGATA under INTERREG IIIB, MEDOCC, SUNRISE and MASCARA under INTERREG IIIC Programmes). DRT services are complementary to conventional, scheduled passenger transport (fixed lines and timetable) as they usually serve dispersed mobility needs, either during hours of low demand, in areas of low population, or where target users are dispersed amongst the general population, e.g. disabled and elderly, tourists. An update on recent developments is found in Mulley and nelson (2009)

FTS and DRTs in particular, can be defined as a transport service which is adapted to meet the needs of users, typically on a trip-by-trip basis with a certain level of flexibility on three operational dimensions (route taken, timing of the service, vehicle used) in

order to alter the service offer and cost parameters in response to the real mobility demand. FTS include a larger range of services and schemes, such as: general use and feeder services; local and feeder services to trunk haul services; replacement of low-frequency conventional services; replacement of fixed routes in evenings or weekends; dedicated/special services, restricted to specific users groups; services in low-density rural areas, efficiencies in social mobility resources, niche urban markets, fuzzy lines between small buses and big taxis, etc.

These different operational schemes have been validated and evaluated from the feasibility and technology aspects to the organization and business model in the above mentioned EU projects with different levels of implementation and results.

From the operational point of view, DRT operations are organised around the concept of a *TDC (Travel Dispatch Centre)*, as the main organisational (and technological) resource supporting the management of the main operation steps involved in service production workflow: the TDC manages the booking requests by users, journey planning and resource optimisation (vehicles and drivers), with the communication to the driver of the new journey or the variations to one already defined.

Usually the ICT-based architecture supporting DRT operations can be described in four main components: *TDC, Communication network, On-board system* and several *DRT user interfacing* possibilities. This general architecture can be implemented in different ways and all existing DRT installations are realised through variations in this basic component layout. The implementation of such installations is made possible by a number of key *enabling I C Technologies*, which include:

- booking and reservation systems to manage the customer requests;
- Internet, IVRS and palm-top devices (PDAs, smart phones, etc.) to assist customer booking;
- dispatching software for allocating trips and optimising resources;
- communication systems and equipment to link the TDC with driver and customers;
- In-vehicle terminals and display units to support the driver;
- vehicle location and monitoring systems;
- Smart-card based fare collection systems; and
- management information systems and other data analysis systems.

3.11.4 The FLIPPER project

In this context, the European Regional Co-operation Programme INTERREG IVC launched the FLIPPER project (a 36 months project starting from September 2008), addressing the above issues in a perspective of the key factor of eco-sustainable and competitive development and social cohesion in cities, rural areas and mid sized towns².

2 FLIPPER project web site www.interreg4cflipper.eu

By capitalising on real results, experiences and good practices gained in previous EU site applications and EU Projects (IV-V-VI FP and Regional Co-operation). FLIPPER aims at establishing a Knowledge Transfer Network among different EU areas and Authorities in the domain of FTS. The main objective of FLIPPER is to achieve capability-building environmental, sustainable and innovative solutions by evaluating the viability and real impacts and by gathering the good practice identified at site level.

Another main objective of FLIPPER is the transfer of experience, knowledge and good practice on FTS through different European Regions in order to increase the social inclusion of disadvantaged citizens groups and/or areas, to reduce energy consumption and environmental impacts thus encouraging sustainable social/economic growth.

The FLIPPER consortium is composed of 11 partners (Local Authorities, Transport Operator Companies and Universities) from 9 EU Regions acting in different transport and mobility scenarios (area characteristics, citizens' demand, mobility schemes, chain actors, operational and organization conditions, etc.). This provides an ideal context for exchanging experiences and good practice on mobility services accessibility, environmentally friendly transport services and for reducing social exclusion of vulnerable citizens' groups. The Lead Partner of the project is the Networks and Mobility Public Transport Authority of Bologna in Italy. The other participating partners are: ATL Public Transport company of Livorno (IT - acting as project technical and financial manager), ATAF Public Transport company of Florence (IT), AUTH University of Thessaloniki (GR), Centre for Transport Research, University of Aberdeen (GB), University of Bodenkultur, Vienna (A), RAL, a non-profit transport organization in Kilkenny (IE), the Municipality of Purbach (A), the Municipality of Volos (GR), the Municipality of Almada (P), and SFM the Public Transport Operator of train services of Mallorca (SP).

FLIPPER approach

The FLIPPER approach comprises the following main actions:

- the exchange of good practice in the field of FTS for enhancing the efficiency of public transport services and the overall sustainability of urban and rural areas by reducing the energy consumption and environmental impacts and for increasing the social cohesion of different disadvantaged areas and /or citizens;
- the understanding of the passengers' point of view and investigation of the socio-economic effects of FTS in the served areas;
- the transfer of well consolidated experiences and best practice among the involved local authorities and other entities with difficulties in providing the most appropriate transport services to disadvantaged citizens and areas;
- knowledge raising both through analytical studies of the local needs and of the possible solutions in order to allow the different partners to identify the most appropriate ICT tools and solutions and their optimal roll-out and operation;

- the increase at local level of the knowledge of new collective transport services;
- the elaboration of guidelines for an effective European policy for collective transport services for cities and rural areas in order to reduce the energy impacts and increase the social cohesion;
- the promotion at local, regional and European level of the concept, approach and results of FTS as a real component of the overall area/region transport chain in order to reduce environmental impacts and increase the sustainability and social inclusion of the different areas/regions.

Based on the above approach, FLIPPER will achieve a set of results / products ranging from the realization of *training courses*, *study visits* and *workshops*, establishing a *network of operators and local Authorities*, development of site *feasibility studies and pilot projects*, production of *policy guidelines* at regional and EU levels, and establish a *Virtual Library* of the FLIPPER products and good practice.

3.11.5 The FLIPPER Flexible Mobility Agency concept

Almost all of the above DRT applications and experiences have been - or are - operated as a single mode, by a single operator as a single element of a potentially larger intermodal transport chain. Moreover, in urban and metropolitan areas, these DRT services have been often applied with little or no integration with other transport modes and mobility schemes, despite there being large opportunities for the improvement of service provision and of the service model itself by strengthening the co-ordination of different intermediate services and their integration within the overall transport service chain. Starting from this situation the Flexible Mobility Agency concept has been set up (mainly in FPV FAMS project, Ambrosino et al, 2005) on the vision that all actors of the DRT service chain, both the different transport operators and the different users groups, constitute a Virtual Community. Through an appropriate e-Business infrastructure, the members of the community will obtain several benefits including: knowledge sharing, improved access to information and services, improved travel service offer, enhanced management of the workflow between the customer and the transport service providers.

The Agency enables the operation of a Virtual/Extended Enterprise of transport operators. Despite the physical location of the operators, the different types of fleet, booking systems, services provided, etc., the Agency manages the entire service chain - from customer booking to service planning, monitoring and control - operating as a unique entity, as “one operator with one fleet and one booking system”, providing an effective response to the mobility needs of the different user groups.

Models and solutions to enable collaboration among the different transport offer chain actors are based on currently available *e-Commerce/e-Business* technologies such as n-tier web-based architectures, portal technology, distributed web services, Internet communication and notification services, information and resources sharing techniques

over the Internet. The Flexible Agency concept means not only flexibility in the transport services delivered to the customer but also flexibility in organising the provision of DRT services in a multi-service and multi-operator context. This flexibility of work and operation is embodied in the concept of a Flexible Agency, enabled by a number of e-infrastructure services.

The implementation of the Agency concept in an European medium size city

For better understanding the concept of FTS Agency we make reference, in this section to the experience developed under the INTERREG IIIIB AGATA project by ATL, the Transit Company of Livorno (one of the partners of FLIPPER project) for the city of Livorno (a medium size Italian city with 150,000 inhabitants). The FTS Agency concept was implemented with the objective to improve the service accessibility and transport information for the final user and citizens by the increased communication level and co-operation of the different actors involved in the transport provision chain (Founder Entity/Local Authority, transport executive, service provider, shop keepers association, E&D association, etc.). The Agency manages the entire service chain – from customer booking to service planning, monitoring and control – operating as a unique entity, through a dedicated Management Centre.

The main components of the Agency are the following:

- a common Travel Dispatch Centre (TDC) for services booking, planning, management and co-ordination of the different operated and offered services;
- a web Portal based offering these different web services:
 - Business-to-Business (B2B) for the integration, interaction and co-operation of the different transport operators and the Agency in order to optimise and co-ordinate the overall available resources.
 - Business-to-Consumer (B2C) for enhancing accessibility to transport services and obtaining more dedicated information for the different user categories (booking by user or association, on-line service situation, next trips, services offered, etc.).
 - Business-to-Administration (B2A) supporting the interaction monitoring and control of flexible services by the Founder Entity vs the contract constraints.

The flexibility of the Agency covers not only the mobility needs of the different user categories but also the operational modalities of service production/operation. The Agency in Livorno acts as technological and operational support for:

- the transport offer by the integrated management of transport services operated in the overall Livorno area and in the different zones, time periods and user categories;
- the co-ordination of the different resources involved (fleet/vehicles, operators/associations/, etc.) on a well defined and agreed set of rules among the actors interacting with the Agency;

- the monitoring and balancing of the service carried out by the different fleet involved in the service provision and contracted by the Agency;
- the service monitoring and control by the Founder Entity;
- diversification of the service access modalities for the users (direct access to the network, booking typologies; web-based, phone, etc.);
- the controlled and co-ordinated service expansion in terms of vehicles and services providers;
- guaranteeing the efficiency and transparency of service management;
- the operational management of TDC and the support to the back-office workflows (booking, planning, communication of next trip to the vehicle, etc.).

The Agency is a natural extension of the current TDC towards web services and network connections increasing the functions and technological components of the *Prontobus* system currently operated in ATL for managing the DRT services.

3.11.6 Towards the large-scale Flexible Mobility Agency in urban areas

From the perspective of our cities for the next decade, taking into account the obligations of countries on the environmental policy/actions (i.e. Kyoto, etc.), the degradation of the economic situation that will affect many city aspects (among other the organization, social cohesion, production modalities, life style, etc.) and the continuously evolving ICT trends (from the current explosion of Wi-max at urban level to the new generation of personal mobile devices), it is realistic to face a mobility demand that will be still more erratic, non-homogeneous and with different degrees of requirements in space and time. To answer these trends it is realistic also to imagine an evolution of the role of FTS and the related Agency concept to a *“Large-Scale FTS Agency”*.

Based on the experience discussed here we are achieving a first relevant evolution of the FTS and in particular the DRT:

- from a first stage where the FTS have been operated in an “holistic” approach with the main objectives, amongst others, of:
 - providing accessibility in marginal areas/time periods;
 - providing direct access to the “overall” information and services;
 - allowing “personalized” services better suited to individual/group;
 - realization of transport services well suited to the area characteristics.
- where the key component of the DRT operation was the Travel Dispatch Centre or the current phase where with the concept of Agency the role of FTS has been enlarged to support the overall public/collective transport services offer in terms of:
 - improving of service access/interfaces;
 - improving the TDC operator backstage workflow;

- integration of different public transport services and operators resources;
- networking of Local Authorities and Transport Executives.

The challenge is now to consolidate the role of the Agency as a “*Large Scale FTS Agency*” acting on the overall “City” as a centre for the integration of mobility services and co-ordination of different actors in a co-modality approach.

Taking into account this scenario the “*Large Scale FTS Agency*” could:

- act as feeder and connecting services to the main conventional public transport network/axes (ie. BRT corridors);
- act as an integration service to the other public transport modalities (railway, ships);
- act as feeder services to the parking areas and management systems;
- serve a niche market of mobility demand (night period, week-end, special user groups);
- co-ordinate with other “city” mobility services (taxis, logistics services, leisure destinations, etc.);
- integrate other flexible services (car pooling, car sharing, etc.);
- support real co-operation with other operators (not only on transport services but also on B2A services or back office services, shared software application/procedures etc.);
- integrate the overall FTS with the city mobility policy and operation schemes.

3.11.7 Conclusions

In the above sections we have described a scenario for urban and metropolitan areas where the role of FTS and the Large-scale Agency could be potentially relevant both with respect to the expansion of the public transport services and the integration and co-ordination of the different modalities and operators as requested by EU with the co-modality policy.

In particular we have analysed some issues faced by the FTS and the Agency concept, impacting on the two dimensions of the service as “operation and technology” (role of FTS, service schemes, TDC operation, Agency concepts, architecture, etc.); however it must be emphasised that a good understanding of the third dimension “organisation/regulation” is essential and this is still very different among the 27 EU countries.

In this respect the FLIPPER project could also provide a real contribution not only because it is involving different entities from different countries but mainly because one of the main objectives of the project is to set a common criteria framework which will enable each region and local Authority to work towards improving their own regulation for the control of FTS. Concerning the Large-Scale Agency it is necessary to work on some key issues such as the following:

- recognize the Agency as an “added value” service for the area and a social cohesion tool;

- support the development of intermediate transport services for the different specific areas and citizens groups;
- support the concept of a unique Agency for the city / urban and metropolitan area;
- public tendering for Agency operation;
- Public-Private Partnership for Agency operation;
- possible interaction/synergy among TDC and Taxi Dispatch Centres and/or with other Paratransit services;
- provide public subsidy for the needed investment, more for TDC management;
- “specific” fare scheme to be analysed;
- push real possibilities of a collaboration among Transport Operators and Citizens’ Associations;
- definition of a specific set of indicators measuring the quality and quantitative of service that are different from those of the conventional transport service.

In conclusion, taking into account the above considerations and the policy and concept of co-modality, it is possible to understand that FTS can become a real key player of the passenger transport in urban and metropolitan areas.

Experiences and applications in Europe: the regional and extra-urban level

4.1 Introduction

This chapter is complementary in scope to the previous chapter which explored experiences and applications of infomobility in practice by highlighting innovation and good practice across a variety of urban and metropolitan locations in Europe. Here the scale of analysis is the regional and extra-urban level.

This chapter considers four quite distinct cases beginning with intermodal real-time door-to-door travel information in the Vienna region drawing on experience in the In-Time project (this is therefore complementary to the case study of user information in the city of Vienna, Section 3.8).

The second example is “Ruhrpilot”: a regional traffic information and management system for one of Europe’s most congested regions. In this case a variety of commercial, administrative and technological factors across jurisdictional borders have been overcome.

The scope in Section 4.4 is overtly rural with a case study from Highland Region, Scotland which describes an application of infomobility for the labour force through development of the Transport to Employment (T2E) service which has implemented the Agency approach to flexible transport based on the use of shared taxis. Finally, a technical analysis of traffic monitoring and control systems on motorways including an analysis of safety in tunnels is presented drawing on experience in Italy.

4.2 Intermodal real-time door-to-door travel information The Vienna case study

H. Fiby, M. Böhm

4.2.1 Introduction

The Vienna Region consists of the three federal states (Vienna, Lower Austria and Burgenland) and is located in the eastern part of Austria. With an area of 23,500 km² the Vienna Region is living space for about 3.5 million people (more than 40% of all Austrians). There exist intensive interactions between Vienna, Lower Austria and Burgenland including in traffic and transport affairs. For the needs of modern mobility up-to-date and publicly available traffic information is of highest importance. In this respect ITS Vienna Region was founded in 2006 as a co-operative traffic management project by Vienna, Lower Austria and Burgenland. One of the first results developed by ITS Vienna Region is the intermodal traffic service homepage “AnachB.at” that is permanently updated and deals with all traffic modes (also combinations of different modes), looks for realistic travel times, is publicly available for free, and covers the entire Vienna Region. An on-trip Multi-modal Real-Time Traffic and Traveller Service will be established within the In-Time project. Here the traveller will be in the position to receive via his service provider personalised travel information during his trip with an indication of actual delays and possible re-routing information.

4.2.2 The ITS Vienna Region project

ITS Vienna Region emanates from the Viennese Traffic Management Initiative (VEMA) which was established in the year 2001. During the development of VEMA it became obvious that traffic management only makes sense with a regional perspective.

This means initially the integration of Vienna, Lower Austria and Burgenland (Vienna Region) and in the medium term the integration of the total Region in the border quadrangle between the Czech Republic, Slovakia, Hungary and Austria (CENTROPE) as well as the other Austrian federal states. The first consequence was the founding of ITS Vienna Region in 2006 as an independent project embedded in the public transport association of the Vienna Region (VOR).

Objective and results

The major objective of ITS Vienna Region is to establish a complete image of the traffic situation as a basis for a regional, intermodal and dynamic traffic information and routing service. The results are an intermodal network representation for all traffic modes and an integrated co-operative traffic management system combining information, monitoring, controlling and regulation as well as the optimisation of the traffic system. In the medium term this integrated co-operative traffic management system should be extended nationally as well as transnationally throughout the CENTROPE Region.

To generate an integrated on-line traffic model, ITS Vienna Region needs on-line data of the actual traffic conditions for its shared traffic data pool. These traffic data are provided by numerous ITS-partners in the form of on-line sensor data, incident and editorial data, planned actions and floating car data as well as real-time data on public transport.

The dynamic traffic information system AnachB.at

In summer 2007, the first prototype of a dynamic traffic information system combined with a door-to-door journey planner was established for all traffic modes (car traffic, public transport, cycling and walking). In summer 2008, during the UEFA European Football Championship, this prototype was tested as a free Internet application.

Since 18th June 2009 ITS Vienna Region provides complete dynamic information about traffic conditions and an intermodal routing service for all three federal states of the Vienna Region, including a routing service for cyclists and Park&Ride information. These services are publicly available for all travellers in the Vienna Region on the new traffic service homepage AnachB.at.

In the long term AnachB.at will be adapted for mobile phone use (pilot project for iPhone until the end of 2009) and expanded throughout Austria and the total CEN-TROPE Region. AnachB.at is seen as the most innovative traffic service homepage of its category Europe-wide, because all services are:

- permanently updated
- for all traffic modes (also combinations of different modes)
- with realistic travel time
- publicly available for free
- for the entire Vienna Region

4.2.3 The next step – Multi-modal On-Trip Real-Time Traffic and Travel Information - In-Time

The next step will be the provision of interoperable and multi-modal Real-Time Traffic and Travel Information (RTTI) On-trip Services to the end-users within the In-Time project. These services will influence the on-trip travel behaviour of the single citizen by optimising journeys also taking the energy consumption into account. The community will be the users of mobile devices or navigational devices. Very important in this concept is the interoperability which ensures the take up of this solution in several places all over Europe. A central part of the In-Time concept is an interoperable and multi modal Regional Data/Service Server (RDSS), which is a service-oriented middleware infrastructure providing a number of data/services, covering

- individual traffic,
- public transport,

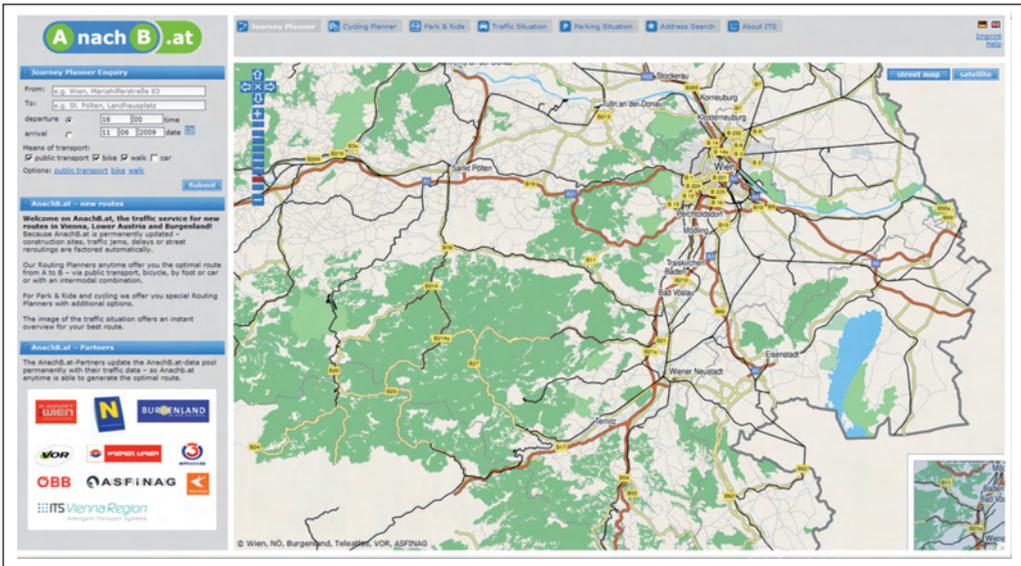


Figure 4.2: Web-interface AnachB.at

- weather information,
- location based services,
- intermodal transport planning,

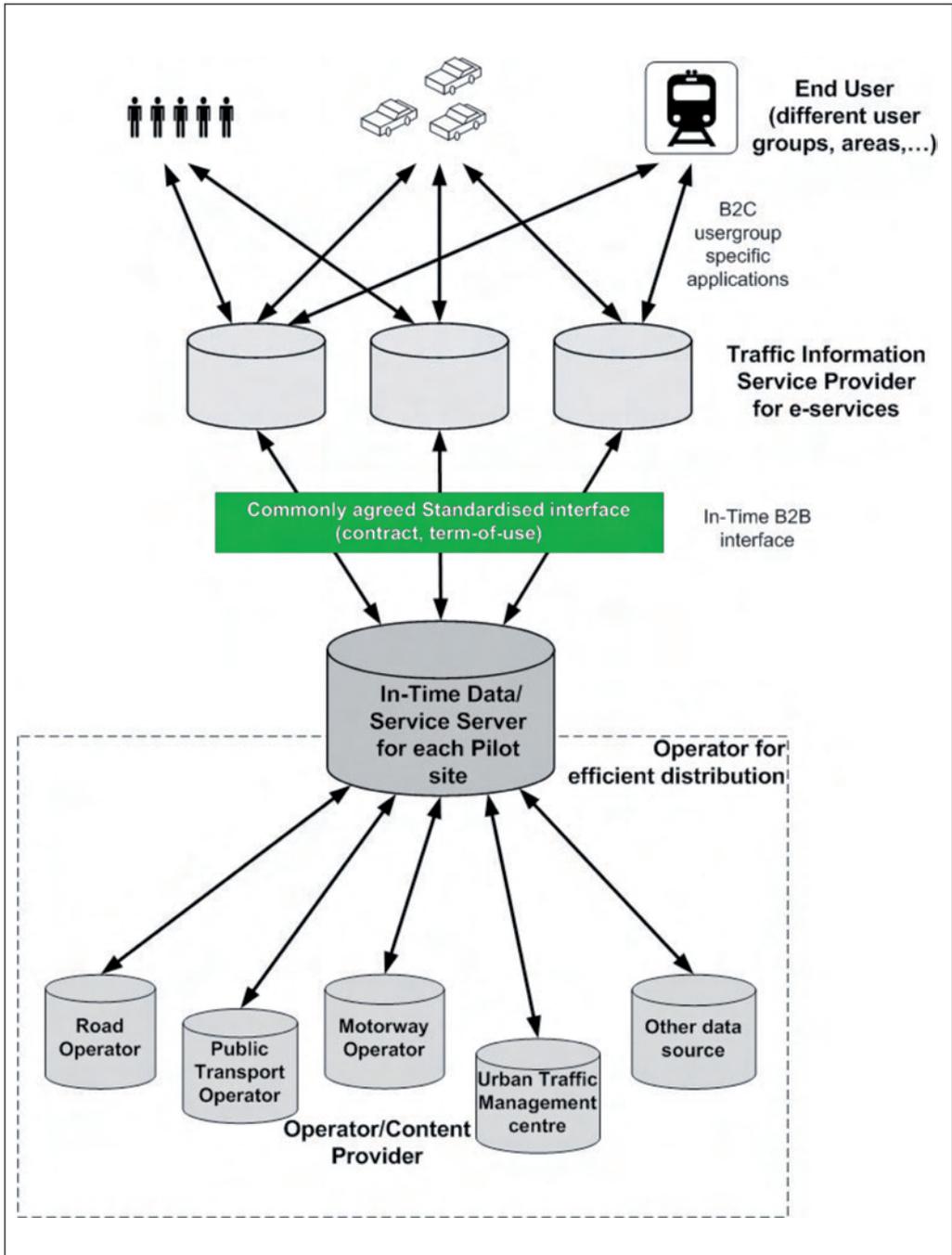
and enabling the operation of end-user applications (e-services) through Traffic Information Service Providers (TISP).

In this way all data of the single infrastructure operators within one city/region can be accessed via a commonly agreed standardised open interface which will be implemented at regional level (see Figure 4.3, next page).

This ensures the easy access of real-time multi-modal traffic data for external TISPs, and it ensures the easy access to all urban traffic related data within one region resulting in the distribution to the end-users via several consistent information channels and in parallel enhancing user acceptance.

Pilot Tests within In-Time

The In-Time solution with the commonly agreed standardised interface will be implemented and operated at 6 European pilot sites. Via this interface interoperable intermodal real-time Traffic and Travel Data will be provided to the European TISPs. This ensures that they will be able to offer the same intermodal end-user service within all pilot cities of more than 8.6 million inhabitants. Beside Vienna this system will be tested in Brno, Bucharest, Florence, Munich, and Oslo.



172 Figure 4.3: Concept of the In-Time Regional Data/service Server (RDSS)

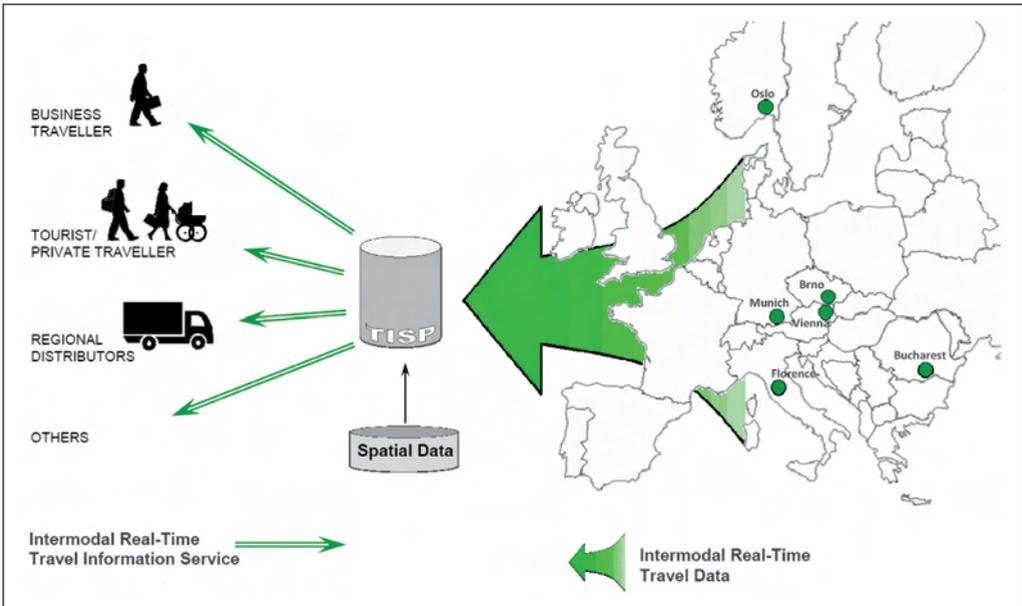


Figure 4.4: Pilot Tests of In-Time

With such a system it is expected that traveller behaviour will change to enforce modal shifts and modal splits by using In-Time services. During the pilot operation the individual traveller behaviour will be conducted with quantitative methods for data collection with a required minimum number of 150 test persons. This change of traveller behaviour will result in less pollution and CO₂ emissions, less particle emissions, and less noise.

4.3 “Ruhrpilot”: a regional traffic information and management system for one of Europe’s most congested regions

F. Logi, L. Ramachers, W. Reints

4.3.1 Introduction

The Ruhr valley is Germany’s largest conurbation and one of the largest industrial areas in Europe (Figure 4.5). In the Ruhr valley more than five million people live in 15 cities spread over an area of over 5000 km² and closely connected by a dense network of motorways, highways, and railways. Everyday over 50 local authorities and more than a dozen regional public transport providers are responsible for guaranteeing mobility to over six million travellers on one of the most densely travelled networks in Europe. On May 30, 2006, in time for the 2006 Soccer World Cup the “Ruhrpilot” mobility

information system successfully started its operations, with the provision of a variety of on-line mobility information services. Several local administration authorities, public transport providers, universities, and private companies for the first time have joined to form a consortium for the on-line provision of real-time regional mobility services that enable travellers to reach their destinations faster and more safely using their preferred mode of transport. With the provision of information for the areas of Bochum, Dortmund, Essen and Gelsenkirchen, the project had only reached its first phase. By the end of 2007 the whole Ruhr Valley was connected with a larger set of mobility services.

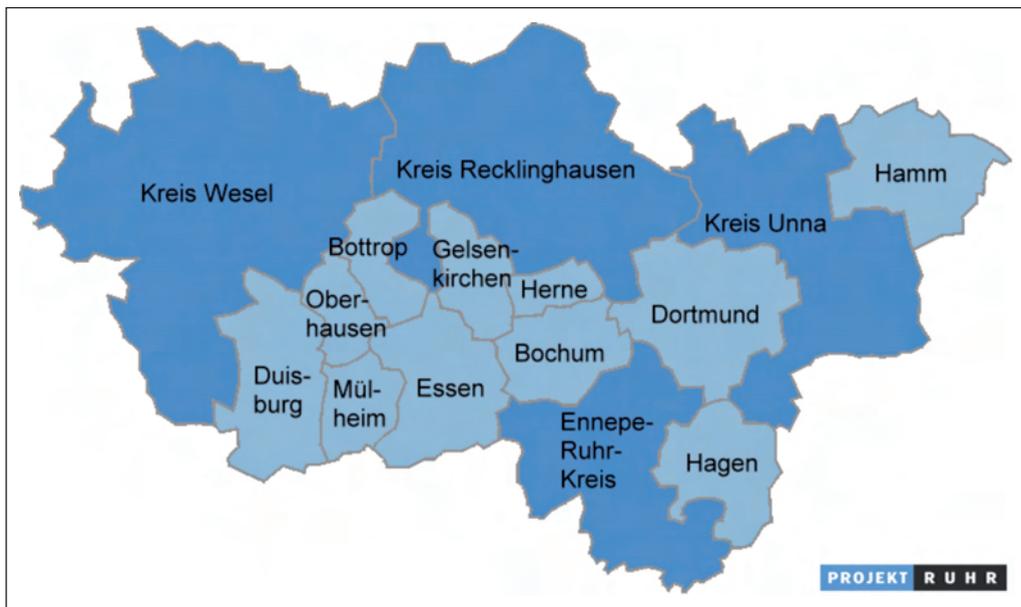


Figure 4.5: Ruhr, the region covered by Ruhrpilot

The “Ruhrpilot” mobility information system offers an innovative approach to inter-jurisdictional transportation management for the Ruhr metropolitan area. The Internet website “www.ruhrpilot.de” offers detailed and up-to-date traffic and parking information and traffic announcements (Figure 4.6). Planned events and sudden incidents that affect traffic circulation are reported with a precise indication of where the problem is located and how long the problem is expected to last. A route planner indicates a suitable travel route that takes into account both current traffic conditions as well as schedules and delays of public transport. The provision of dynamic car-parking information facilitates the search for a parking space by informing drivers on how to get there. This Internet service guides drivers who are unfamiliar with the area towards available parking spaces, parking garages and underground car parks, informing them on the number of available spaces, on the opening times and on the parking fees.

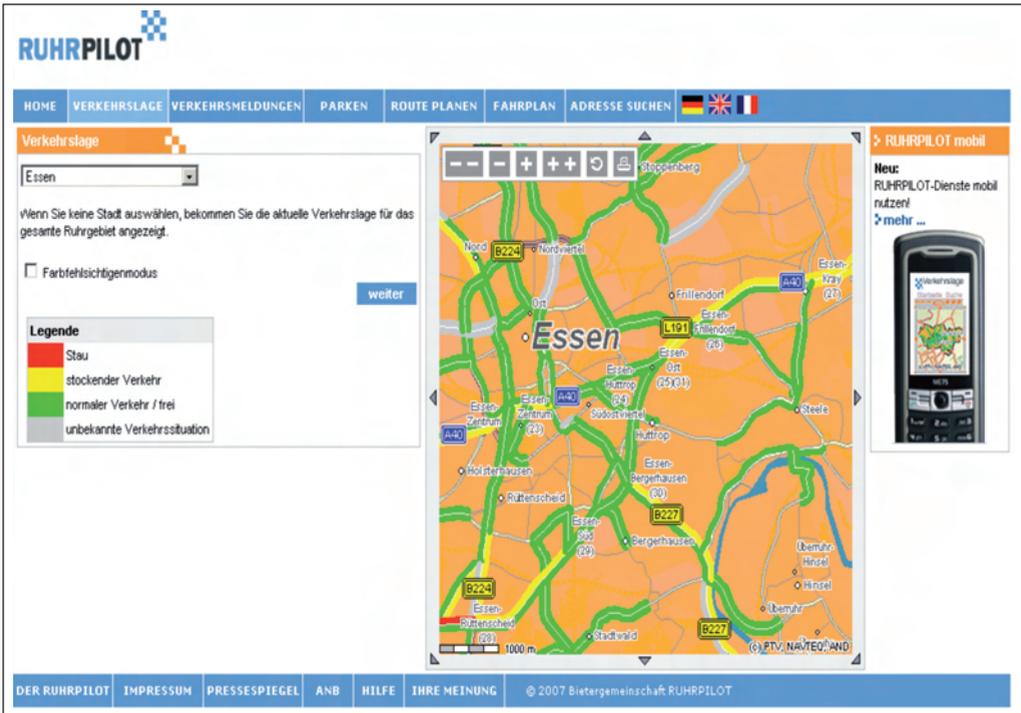


Figure 4.6: Traffic conditions and routing information available from the web-site “www.ruhrpilot.de”

Neither route guidance nor dynamic traffic information services are necessarily new.

The particularly innovative aspects of Ruhrpilot are the size of the network and the complexity of the interaction among the parties involved: for the first time in a complex conurbation such as the Ruhr region, all mobility-relevant data from different transport networks and from a variety of public agencies are electronically collected, stored in a common data base, processed, and made available to users in a wide range of multimodal mobility services.

The complexity of the Ruhrpilot project required a multi-phase plan, aimed at gaining concrete benefits from the various building blocks as early as possible, and at the same time testing the validity of the various interim steps. The project successfully completed the first phase as scheduled: as of May 30th, on time for the 2006 Soccer World Cup, Ruhrpilot gathers data and provides information on the road network in four of the main cities in the Ruhr Valley.

By the end of the project the whole multi-modal network of the Ruhr Valley will be connected. A wide range of mobility information services will be available, including traffic forecasting, through a simulation and projection mechanism which will yield traffic conditions expected in the short term (current day), the medium term (following day up

to two weeks) and the long term as well (a few weeks up to a year). The simulation-based forecast will compute expected speeds, flow conditions and travel times for up to an hour in the future. The forecast will be updated every minute and best routes (either by car or by public transport) will be deduced. Information is broadcast via radio, navigation systems and WAP/UTMS-enabled mobile phones. Transit departure times and connections as well as car park occupancy are shown on cell phones displays.

4.3.2 *Complex interactions over jurisdictional borders*

As mentioned, the complexity of the Ruhrpilot derives not just from the size of the area affected, but even more from the variety and the interconnection of the forces in play, which determine the flow of the current activities:

- **Commercial:** this relates to the development of a valid business model which achieves the project goals, justifies the investment, and protects the interests of the shareholders.
- **Administrative:** this requires the agreement among all involved agencies on issues such as data ownership and information sharing, the establishment of management strategies and their jurisdiction, and the operations of control infrastructures.
- **Technological:** this involves planning the system architecture; setting-up the data communication network, and developing and deploying the interconnected systems.

Commercial issues: Project as a Private Public Partnership

The customer which issued the order for construction of the traffic management control centre is Projekt Ruhr GmbH, a 100% subsidiary of the state of North Rhine-Westphalia. As part of the project and in the context of an EU-wide call for tenders, a consortium headed by Siemens was awarded the contract for construction of the centre and its operation over a period of ten years. In addition to Siemens, the bidders included PTV, the DDG Gesellschaft für Verkehrsdaten mbH, and the EVAG Essener Verkehrs AG. The project was conceived as a Public Private Partnership (PPP) – see Figure 4.7. The company Ruhrpilot Besitzgesellschaft mbH is the owner of the infrastructure for the Ruhrpilot systems and is responsible for financing, supervising construction, and ensuring quality management. These contractual ties are an important prerequisite for the involvement of the operating company, since they provide the necessary contractual safeguards, such as for the creation of value-added services.

The public authorities invest over 28 million Euros for the construction of the system, while the rest, about 20 million, will be covered by the private consortium

Administrative issues

The Community Transport Financing Act (Gemeinde Verkehrs Finanzierungs-Gesetz, GVFG) made it possible to integrate the different transportation systems into the co-

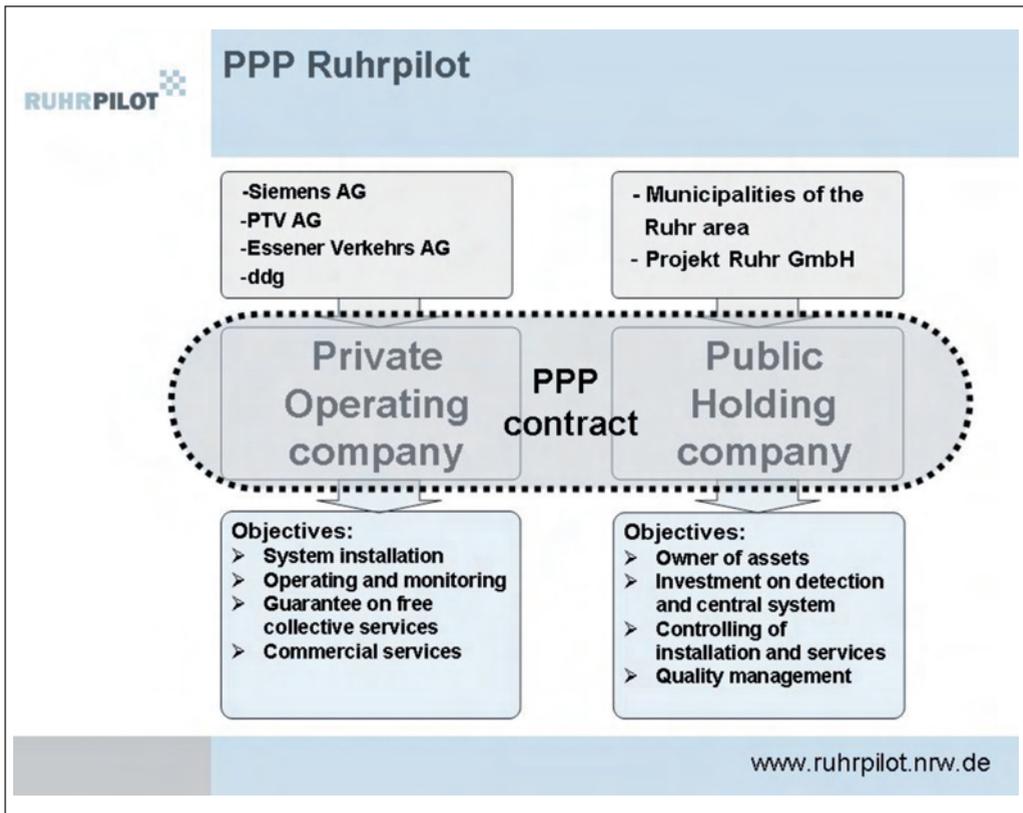


Figure 4.7: The scope of the public-private partnership Ruhrpilot

operative venture and also to cover the costs for the necessary expansion of existing systems. The amount of financing contributed by the communities is limited to their complementary share. Currently, 15 of the most important towns and cities and five transport companies have joined the project in a co-operative capacity, and talks on collaboration are being conducted with other transport companies. The contractual involvement of the transport operators is the basis for this intermodal and multi-modal traffic management system.

An important first result of the co-operation included the agreement on shared data among the communities: a common road network for which traffic data is made available by the responsible jurisdictions. Cities have agreed on providing traffic data for their sub-networks at no cost and in return expect estimated traffic conditions on the whole area resulting from the fusion of the various sources. This step is by no means a trivial one, considering the sheer number of agencies involved, which for the first time have agreed to join a consortium.

Technological issues: Unique interconnected data network for one region

Significantly new is that Ruhrpilot has brought together not only different stakeholders from politics, administration, and industry, but also technologically heterogeneous transport management systems. A positive effect of the cross-jurisdictional co-operation is indeed that the Ruhrpilot portal provides mobility information from a variety of different systems, from freeway and urban congestion, to tram and train schedules and delays, to parking availability.

The complexity of the interacting forces requires a sophisticated technological solution, characterized by a modular concept and capable of satisfying the various requirements, taking into account the dynamics of the project. Thus, for the system architecture, a multi-layer hierarchical approach was selected, as shown in Figure 4.8.

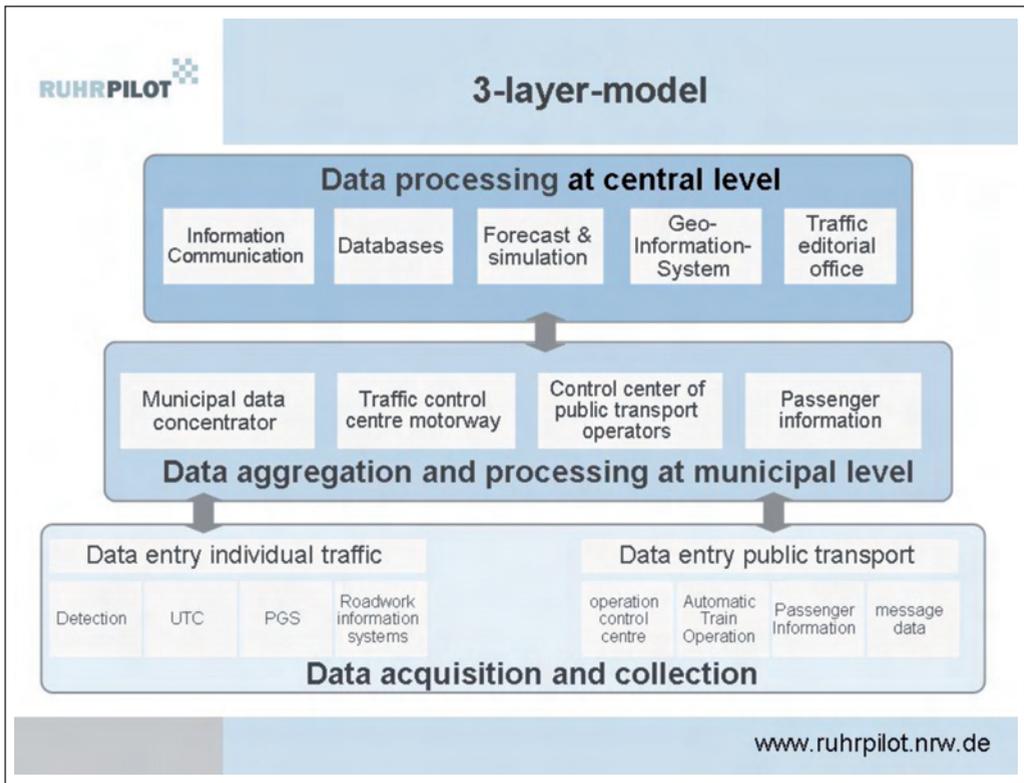


Figure 4.8: Ruhrpilot’s multi-layer system architecture

A distributed network of traffic management systems, based on the solutions “SITRAF-FIC Concert” and “Traffic Eye” for traffic data acquisition and management, forms the base of such architecture. The Traffic Eyes are autonomous solar-powered systems which assess traffic conditions and provide detailed and reliable information such as traffic

density and level of service, without the need for expensive cabling. The transportation management system SITRAFFIC Concert consolidates information from individual control systems, processes it and stores it through its data management system, makes it available in adequate formats to the connected systems, to planners, to transportation management operators, and to travelers thorough a GIS and a friendly Web-based GUI, in order to optimize traffic control and provide the best transportation information available (see section 3.6 for an application of SITRAFFIC in Berlin).

Other peripheral sub-systems include sensors and actuators in the broad sense, i.e., environmental sensors, floating cars, signals, VMS, parking guidance signs, etc. Ruhrpilot continually collects electronic data on the traffic situation from 4,480 detection points on federal freeways and, for the first time, on federal and state highways as well. Over 700 of these detectors have been installed throughout the region.

A higher level is that of the various control sub-systems, (UTC, PGS, roadwork management, etc.). The sub-systems of any given city interact with a so-called “data concentrator”, a higher system in the hierarchical level, with the task of funnelling data coming from the various sub-systems (for a given city) and providing the interface to the central level.

The central level is essentially where data is transformed into information; at this level, data from the various concentrators are fed into a content platform. The content platform, the core of the Ruhrpilot system, contains the modules for traffic modelling and estimation and makes use of databases containing current and historical traffic data, incident and special event data, as well as the multi-layer digital maps and GIS. On top of the content platform is a service platform, which offers the required technological base for the provision of a variety of services. The current service concept envisions the provision of two levels of services: a “basic” level and a “value-added” level. Basic services include services for the citizens, such as collective provision of traffic conditions via Internet, estimated travel times, parking occupancy and special events, as well as services for public authorities, as agreed in the contract. Value-added services have two main target groups: public authorities are offered services such as consulting based on the assessment of the collected data pools, environmental monitoring, and event management. Companies are offered tailored mobility information services for the local Ruhr area. Further service providers, acting at national or international level may purchase the generated content.

The heart of the modern traffic management system is the new Ruhrpilot control centre at Schweriner Strasse 6 in Essen together with the computer centre containing more than 50 servers in Berliner Platz. Here, the latest traffic data from detectors and measuring points as well as information on the occupancy levels of multi-storey car parks are collated. Signals from community traffic computers, the control units of community traffic lights, the traffic computer control centres as well as from the “electronic timetable

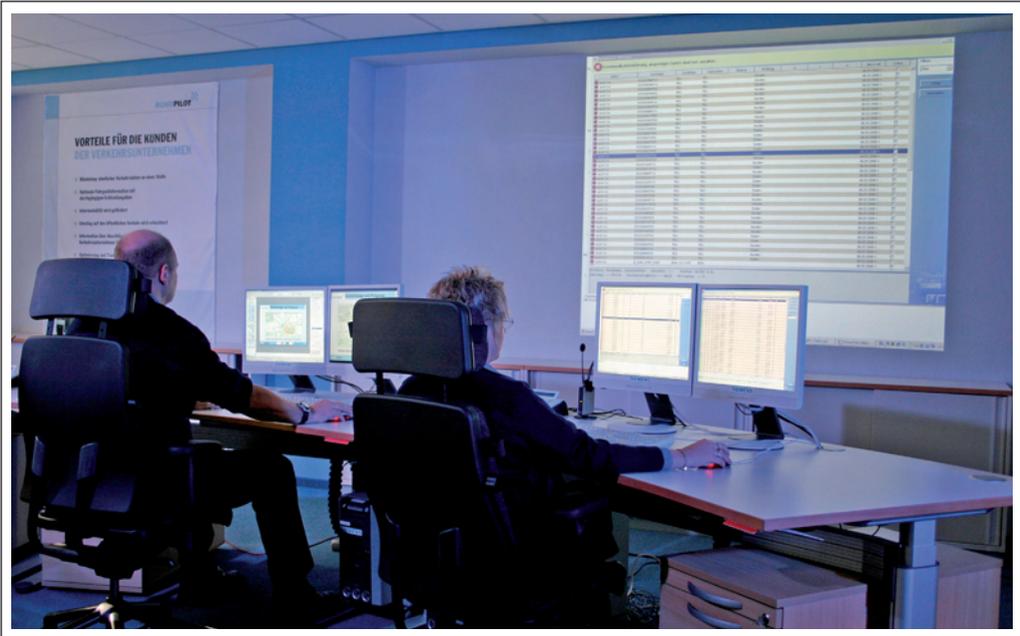


Figure 4.9: The traffic management centre in Essen

information” system of the interconnected Rhine-Ruhr traffic network are integrated for purposes of analysis. Further information on the Rurhpilot, the service provided, the time plan remaining to project completion, as well as additional press reviews are available under: <http://www.siemens.com/traffic> and <http://www.ruhrpilot.de>

4.4 Infomobility for the labour force: Transport to Employment in Highland Region, Scotland

J.M. Cooper, S.D. Wright, J.D. Nelson

4.4.1 Background to the Transport to Employment Scheme

The ability to access an employment opportunity, and the need to rely on continuing reliable transport to work is significant, indeed essential, in taking up and maintaining employment regardless of location, employment type or individual circumstance. The demand for access, in this and other domains, is widely recognised (See: Brake et al 2004) as both a need and an issue. In more rural communities services operated by traditional fixed route transport have come under increased operational pressures and a lower potential market, as a result of a reducing public subsidy, increased car ownership, and expectations of access, which have typically resulted in heightened difficulty

in gaining access and a deterioration of service levels to those without alternative. This is countered, in some instances, by bus-based Demand Responsive Transport (DRT), but even this may fail to address the need to turn up on time, regularly and across all time periods essential to getting to work.

The Transport to Employment service (T2E) provides an alternative method of access to work, and has sought to quantify and to address the gap between home and workplace. The service provides an Agency approach to mobility (see Section 3.11 for contrasting experience in Italy) and access to employment and seeks to enhance and complement transport in areas where traditional services exist, and provide new access in areas where it does not. T2E services are provided only where other forms of transport are not available, charged at a rate consistent with bus fares, and supported in initial use where costs of transport may also act as a barrier to gaining employment. The concept was trialled as a pilot in East Sutherland for 12 months to March 2006, and has since developed to a full application across Highland Scotland, and in separate schemes in Skye and Lochalsh, Scotland; Dumfries and Galloway, Scotland; and in Northern Ireland.

Experience gained in the operation of T2E suggests that, in reality, rural communities face a number of number of challenges in gaining access to work. Lack of transport is a significant and absolute barrier, but should also be considered in combination with other factors that may have an impact on employability. These include the need to increase access to training and to childcare as an integral element for some in increasing access to work, and significantly to provide services at fares that are affordable to individuals.

The result of achieving an appropriate and affordable service can be to increase individual participation, create new access to work, create a greater opportunity and access to workforce for an employer and ultimately contribute to the surrounding community as local economic benefits accrue, through increased local expenditure; and to the state, as support and welfare payments fall as a result of increasing employment.

Identifying needs, demand and gaps in existing services

The initial service pilot focused on East Sutherland, in the Highlands of Scotland (Figure 4.10, next page). The pilot area had a number of traditional fixed route services with a variety of more flexible transport services, including a number of 'Dial-a-Ride' DRT services operating two days per week across three areas: Lairg, Bonar Bridge and Dornoch.

Existing bus and rail routes offered, and continue to provide, a significant level of access along their routes, and are a vital part of public transport in East Sutherland. Existing services operate regularly North-South along the Eastern seaboard. Inland fixed route services, however, are far fewer in number, and often are only available for a small part of the day or on limited days of the week. Difficulties arose in accessing workplaces from inland communities where bus services are limited or are not available. Negative

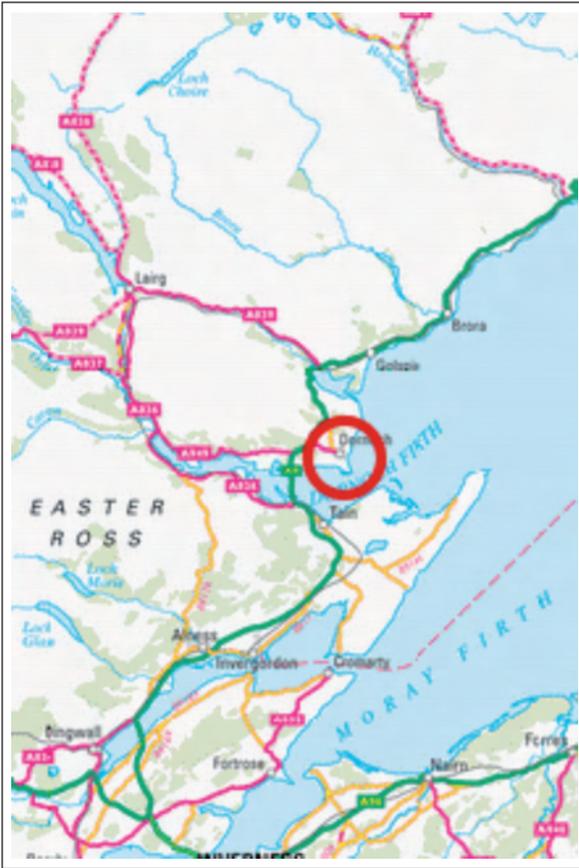


Figure 4.10: The Highland T2E Service area

impacts were also identified within existing corridors at times when services were limited or not running, typically by time of day or day of week, and in instances of journeys diverging from corridors to employers away from the bus route. Some instances of seasonality also exist where services operate in tourist seasons, and often in instances where buses are provided on school days only.

The need to access workplace away from traditional bus routes, and outside traditional hours of operation became a focus in the development of the T2E service. Gaps exist and are visible in inland communities at most times, and in coastal communities away from peak operating hours. The needs and demands of transport within the T2E area were not, therefore, felt to be competitive with existing services, nor was it felt appropriate to provide replacement services

along existing routes T2E services supplied on the premise of offering access only in instances where none had previously been available, where the absence of a T2E journey would result in no journey being made.

Gap Identification

The basis for T2E provision was identified as, and remains, to provide services only in instances where other forms of transport are not available. The concept is simple, and generally well understood; where an alternative is available and appropriate this should be used in preference to T2E. The concept is also relatively well accepted in practice, and applied as a number of tests (see Table 4.1) conducted at the point of entry to T2E.

Individuals with existing and appropriate access to transport are not eligible for transport using T2E, while those with partial access are able to use T2E where other forms of transport are not available. Young adults with partial use of a family car are classed as having no access to a car.

Indicator	Status	Action
Individual has access to a car?	Yes, own car	T2E is not provided
	Yes, partial. Where partner has prime use of car	T2E may be provided when car is not available
	Yes, partial. Young adult with partial access to parents' car	T2E may be provided.
	No	T2E may be provided
Fixed Route Bus available?	Yes, on route and at times required	T2E is not provided*
	Yes, for a portion of the route and at times required	T2E may be provided to access fixed route services
	Yes, but not at times required	T2E may be provided where traditional services not available, defined as: in excess of 45 minutes delay between boarding or alighting and notified shift times
	No	T2E may be provided
Dial-a-ride available?	Yes, partial based on days / times of provision	T2E may be provided as per fixed route bus.

* Exceptions may apply where individual circumstances preclude use of fixed route services e.g, specific accessibility requirements not met by traditional provision

Table 4.1: Identification of T2E availability

4.4.2 Service Design

As the extent of existing transport provision have become apparent, the service has sought to fill gaps and address issues initially identified, and updated in light of operational experiences accumulated during the pilot operation.

An initial survey completed during the developmental stages of the service, and reinforced by continuing surveys of user opinion have identified three primary issues in accessing employment: time of travel, vehicle reliability and journey cost.

Time of Travel

The biggest single issue in the provision of transport relates to the need to travel to work at times where existing public transport is not available. Early morning shift starts and late night shift ends were shown not to match existing fixed route services, particularly in 183

instances where travel necessitated access to main route corridors from inland locations. The ability to access work was hampered by an inability to get to main route bus stops or stations. This was also felt to be the case in instances where Dial-a-Ride services operate and this was exacerbated by some services operating on specific days of the week only.

Route Reliability

A further issue reflected the perceived, and in some instances actual, shortfall in reliability. Reliability was also identified as a key issue to employers for whom punctual arrival of staff can be affected by late running public transport services. Comments from local employment agencies involved in the development of T2E also suggested that low levels of reliability in public services would result in employers preferring to employ individuals with access to a car in preference to those accessing the workplace by any other means.

Journey Cost

The impact of transport costs also rated highly as an issue in the take up of employment. A logical relationship exists between the ability to afford transport and the ability to access more distant employment opportunity, and this provides a self-imposed barrier to employment. It may also be seen as a destructive social cycle, where lack of employment reduces ability to afford transport which reduces the ability to seek employment. An on-going assessment of costs and affordability had been built into the T2E service, and has resulted in use of a two stage cost model, in which service subsidies are applied in initial use of the service, while a cost recovery rate is applied for later use, at a stage where an individual has achieved greater financial stability.

4.4.3 Service Delivery: T2E Agency for Mobility

T2E has developed over time a focused low cost service reflecting the need to provide reliable access to work, without imposing costs that would themselves create a barrier to employment. The service is centralised to a single Agency (see Figure 4.11) providing administrative and booking support. The T2E Agency purchases supply from a mix of taxi and community transport companies, on the basis of a common contracted supply model. Contracts are agreed by negotiation, with costs agreed typically 40% less than published regional taxi tariff, with a benefit to the individual user of a lower cost of transport, and to the supplier on the basis of longer term business development.

The centralised Agency acts as a one stop shop in providing information on existing services, booking T2E services and arranging for payment to suppliers and fare collection from users. The Agency also accommodates bookings by a variety of means, both technologically advanced, and basic, given the range of technologies available to and used by both operator and passenger.

The mechanisms for information exchange to enable mobility for the T2e scheme are illustrated in Figure 4.11. A low-technology approach has been adopted to match technologies available to the primary service stakeholders, Job Seekers and local transport providers (small local taxi operators and community transport organisations).

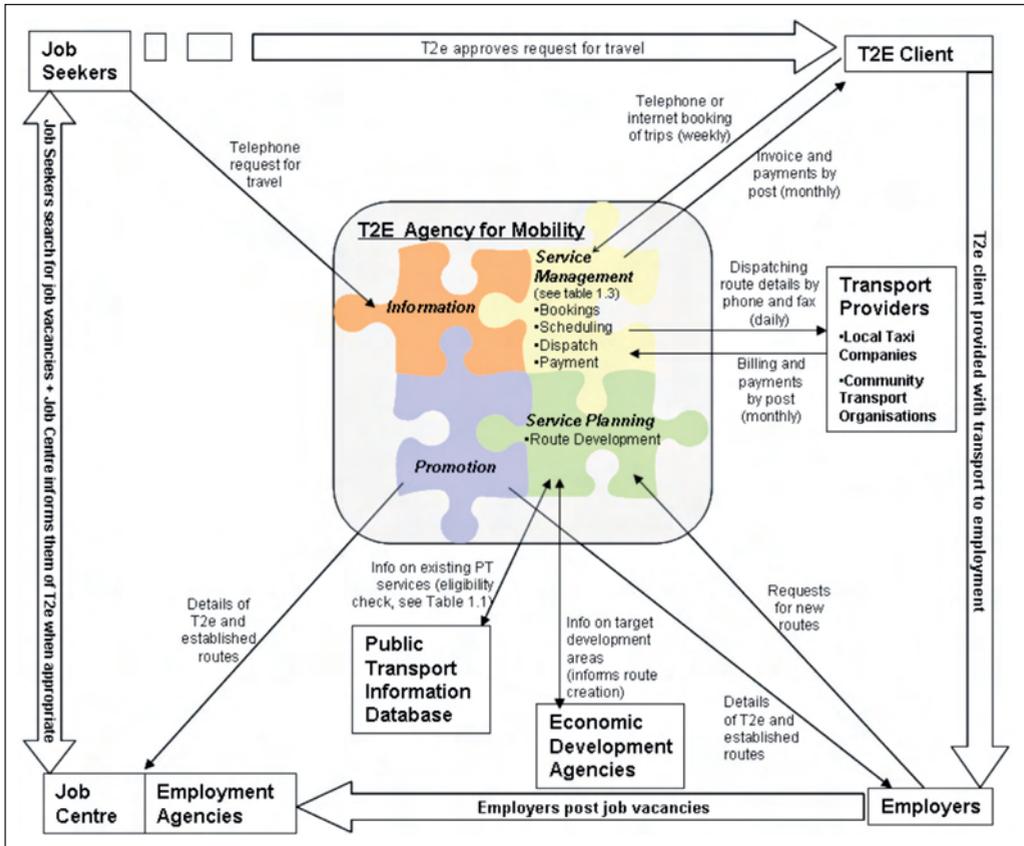


Fig 4.11: T2E Agency for Mobility

The processes illustrated by the outer ring of Figure 4.11 involve:

- i. Employers informing the Job Centre and local employment agencies of job vacancies.
- ii. Job Seekers searching for suitable vacancies at their Job Centre or local employment agency and if a suitable vacancy is found in a T2e service area then the Job Seeker is informed of the service and advised to contact the T2e Agency for Mobility.
- iii. Job Seekers contacting, by telephone, the T2e Information service within the T2e Agency for Mobility to find further details and make a request for travel to the job location through T2e.

- iv. The Job Seekers request for travel is assessed by the T2e Agency for Mobility service planning manager according to the need of the individual (see Table 4.1) and the suitability of existing T2e routes, or if no suitable routes exist the availability of funds to introduce a new route. This will also take account of appropriateness of destination location for other potential job seekers.
- v. If the request for travel is approved the Job Seeker is informed and becomes a T2e Client.
- vi. T2e Clients make telephone or Internet booking requests every week and are billed for their use of the service every month. Billing and payments are done by post.
- vii. T2e Agency for Mobility dispatches route information each day to the Transport Providers contracted to provide the service. This is done by phone and fax as these providers typically have no intelligent technologies in their office or vehicles to manage the mobility process. Billing and payments are again conducted by post and handled by the T2e Agency for Mobility service manager.
- viii. The T2e client is transported from their home address to their new job location at the times required by the transport provider.

Alongside the delivery aspects of the T2e service, the T2e Agency for Mobility is also involved in promoting the service to employers and employment agencies. It is hoped that this will in time prompt service requests directly from these organisations to introduce new routes which they are willing to partly support or for already established routes with spare capacity to carry fare paying existing employees thereby reducing further the route subsidy required.

4.4.4 Operational Experience

The uptake of T2E services has been significant and allowed for continued development of the service in new areas. The service has provided regular and frequent access for over 80 individuals in the Highland area alone (c. 300,000 passenger miles pa), while the centralised Agency has proven positive in reducing overall costs of service provision, with individual trip subsidies below rates experienced in the majority of other rural transport modes, currently less than £4 per passenger trip over the course of a year, compared (Halden 2005) to typical costs between £5 and £10 pounds for other forms of DRT, see Table 4.2.

As the use of T2E has increased, the Agency has been able to identify and introduce a number of automated systems to the booking and administrative procedure; although it should be pointed out that a trade off exists between the benefits of increased automation resulting from the use of intelligent technologies, and the benefits of personal (and often more flexible) solutions achieved through manual means. Table 4.3 identifies alternative solutions across the Agency, and highlights the methods adopted by T2E.

Market	Subsidy costs per trip			
	<£2.00	£2-£5	£5-£10	£10-£20
Premium Service	Target for commuter service			
High Value to Agency	*Transport to Employment*		Joblink, Social and geographical Ambulance Serve	
High Care Needs			Typical dial-a-ride Social work transport	Medical Ambulance service
Best Value Public transport	Typical shared taxi (bus replacement)			

Table 4.2: Typical public subsidy costs per DRT trip

Domain	Technology	Benefit (Weakness)
Bookings	Automated: Internet Booking System <input checked="" type="checkbox"/> Adopted by T2E	Speed of input, confirmation and reduction in manual input (Limited user access to Internet, need to accommodate non-Internet bookings)
	Manual: Telephone <input checked="" type="checkbox"/> Adopted by T2E	(Almost) universal access, operator check for accuracy and avoiding misunderstandings. (Time consuming and higher personnel costs)
Scheduling	Automated: Vehicle Scheduling Algorithm	Reduction in manual input (Reliance on automated and map driven location details which are subject to change, often at short notice)
	Manual: Knowledge based allocation <input checked="" type="checkbox"/> Adopted by T2E	High levels of accuracy where scheduler knowledge is current. (Cost of manual input)
Dispatch	Automated: In vehicle terminal	Rapid transmission of information (Affected by radio or cellular reception, high per traveller costs in low demand areas, not well suited to contracted multiple operators)
	Semi-Automated Email / Fax Schedule <input checked="" type="checkbox"/> Adopted by T2E	Relies on operators existing dispatch system, does not require additional expenditure. (Limited to the levels of technology employed by contracted operators)
	Manual: Telephoned Order <input checked="" type="checkbox"/> Adopted by T2E	No technological limits (May result in delayed reaction)
Payment	Automated: Smart Card (Stored Value)	System generally trusted by users (Very high levels of capital cost)
	Semi-Automated: On-line credit card payment <input checked="" type="checkbox"/> Adopted by T2E	Widely used system (Discriminates against individuals without access to Internet)
	Manual: Cheque payment against invoice <input checked="" type="checkbox"/> Adopted by T2E	No restrictions in use, widely understood and commonly applied.

Table 4.3: Service Delivery Mechanism and Benefit

4.4.5 Results and Analysis

The extent of take up of T2E services has been significant and is, in itself, indicative of demand for the service. Initial projections of the likely demand for the service have been exceeded, with levels of hidden demand, latent demand, for access to work from small inland communities realised with the expansion of the service, and increased awareness of its availability.

Demand ranges across a number of categories, with a wide range of user ages, and length of unemployment prior to use (Figures 4.12 and 4.13). The service does, however, identify a significant bias toward female use (c.65%) coinciding with a predominance for cars to be used by men in single vehicle households; and a larger number of younger users, where car ownership is not yet an affordable option. The high proportion of users who were previously long term unemployed (>24months) is particularly encouraging.

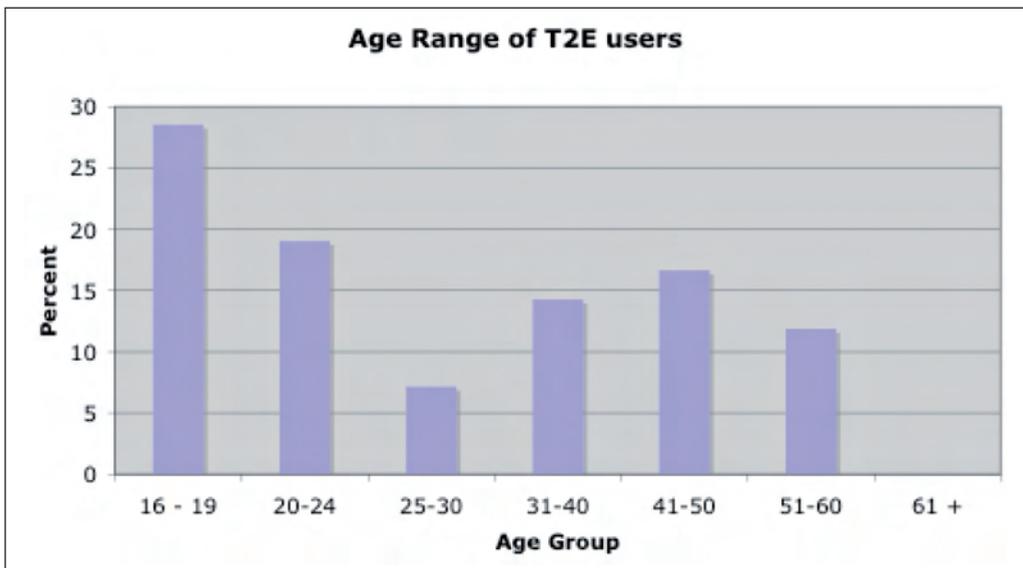


Figure 4.12: User Age Range, T2E Highlands – Source: T2E Survey Oct 2006

Benefit Identification and Measurement

The identification of impacts and benefits arising from T2E, and in other similar transport services, can and should be assessed against a variety of measures. The T2E service impacts directly on the mobility of the individual, and in terms of community accessibility, but is also likely to impact on the employer through wider access to workforce, and on the local economy as an individual spends income in the community. Additional benefits accrue to the wider economy where an individual moves from receiving benefit payments to contributing tax on earnings. While the former is individual and subjective, the latter,

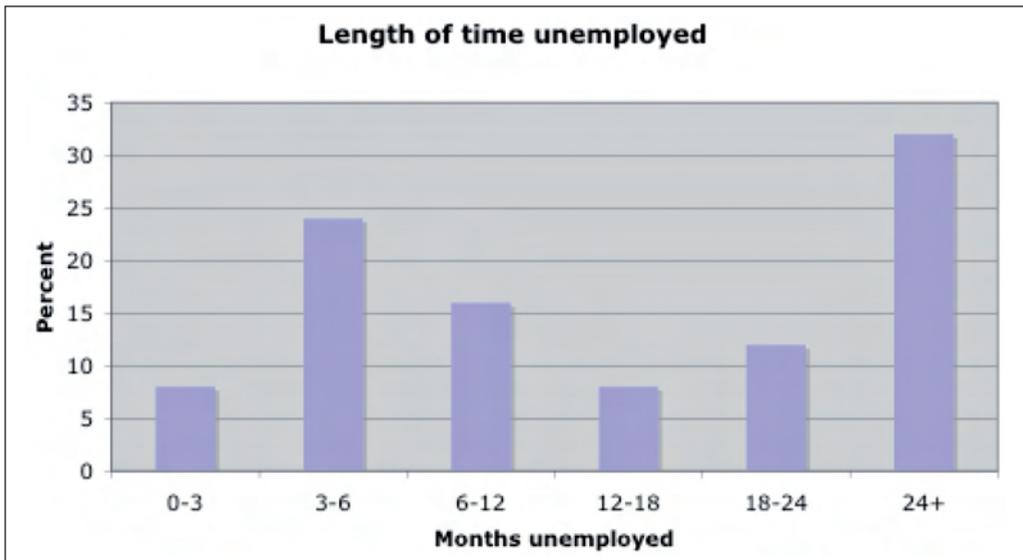


Figure 4.13: **User Length of time unemployed** Source: T2E Survey Oct 2006

reduction in benefit and increased income of tax to the Treasury is objective, and may be assessed in the wider context of Social Return to Investment (SROI).

Initial assessment (see Cooper et al 2006) identified the social benefits that occurred from an initial take up of 19 users, resulting in an SROI rate of return of 6.2:1. Subsequent use has significantly exceeded the target, with lower per capita costs achieved through economies of scale across Highland and other T2E service areas.

Service enhancements have also resulted in a wider range of benefits, and an increased access to journeys including access to childcare, provided as a leg of a journey to work, and increased access to work-related training.

Fine tuning operating practice

The operational experiences and increasing requests for transport have allowed the T2E service to develop and fine-tune its services. A wider range of service types, access to workplace, training and childcare, effectively increases accessibility from the initial employment to a broader base of users. Application of some technologies has increased the effectiveness and efficiencies of the centralised administration, with increased access to on-line services from just under half of registered users. The service has not, however, moved to automated dispatch technologies, as the level of capital costs is felt to exceed the current and predicted benefits. A mid-point in dispatch and ordering including the use of email and fax is encouraged but also remains partial as individual transport suppliers employ differing individual dispatch systems.

4.4.6 Conclusion

The Transport to Employment service has identified and proven a novel approach to access in remote rural communities. Individual and community benefits are high, and represent low levels of individual cost and low levels of support costs, often less than those in more traditional transport modes. The choice of focused small vehicle flexible transport has reduced many of the difficulties in accessing employment; while individual charges remain low the service has demonstrated opportunity and evidence of break even and sustainability over time.

4.5 Traffic flow modelling: a Motorway case study¹

L. Domenichini, A. Giaccherini, N. di Volo

4.5.1 Introduction

Microscopic traffic simulators are tools that realistically emulate the flow of individual vehicles inside a generic network: this is achieved by employing car-following and lane changing models that take into account both global and local phenomena that can influence each vehicle's behaviour. These modelling techniques can be fruitfully applied to analyze both different traffic control strategies and to evaluate traffic safety conditions due to the interaction between vehicles in the traffic stream.

Traffic monitoring and control systems can be modelled in the simulation tool and their performance can be analyzed under different traffic conditions, with references to the possible traffic management strategies and emergency situations. As far as traffic safety is concerned, microsimulation techniques are becoming a very powerful tool: the main problem to keep into account is that a microscopic traffic simulation is an ideal world where no crash occurs, which is due to the basic hypothesis of the car-following model where each vehicle keeps a "safety braking distance".

Management strategies and ITS devices used to monitor and manage motorway traffic conditions inside tunnels have been analyzed by means of a microsimulation tool, with the target of improving both the quality and safety of circulation. To this purpose traffic monitoring and control systems, driver information technologies and tunnel facilities and utilities was modelled in the simulation tool and their performance were analyzed

1 This section is an annotated extract from two previous papers: Domenichini L., di Volo N., Serventi R. (2003) "Microsimulation Model for the New Italian Motorway System A1 – A1bis from Bologna to Firenze", Proc. ASECAP Portoroz International Workshop; and Domenichini L., Di Volo N., Giaccherini A. (2004) – "Identification of Safety Indicators for Road Traffic Management in Tunnels Using Microsimulation Techniques". Proc. II International SIIV Congress, Firenze.

under different traffic conditions, with references to the possible traffic management strategies and emergency situations. This work refers to results obtained with studies aimed to identify potential traffic parameters allowing prediction of the occurrence of critical conditions inside tunnels. For this purpose the relation between the main flow parameters, such as traffic composition, speed, density, time/space headway between vehicles and longitudinal accelerations was analyzed in order to quantify the degree of vehicle interactions occurring in the different possible road service conditions, assuming that the probability of accident should increase when the vehicle interactions become more frequent.

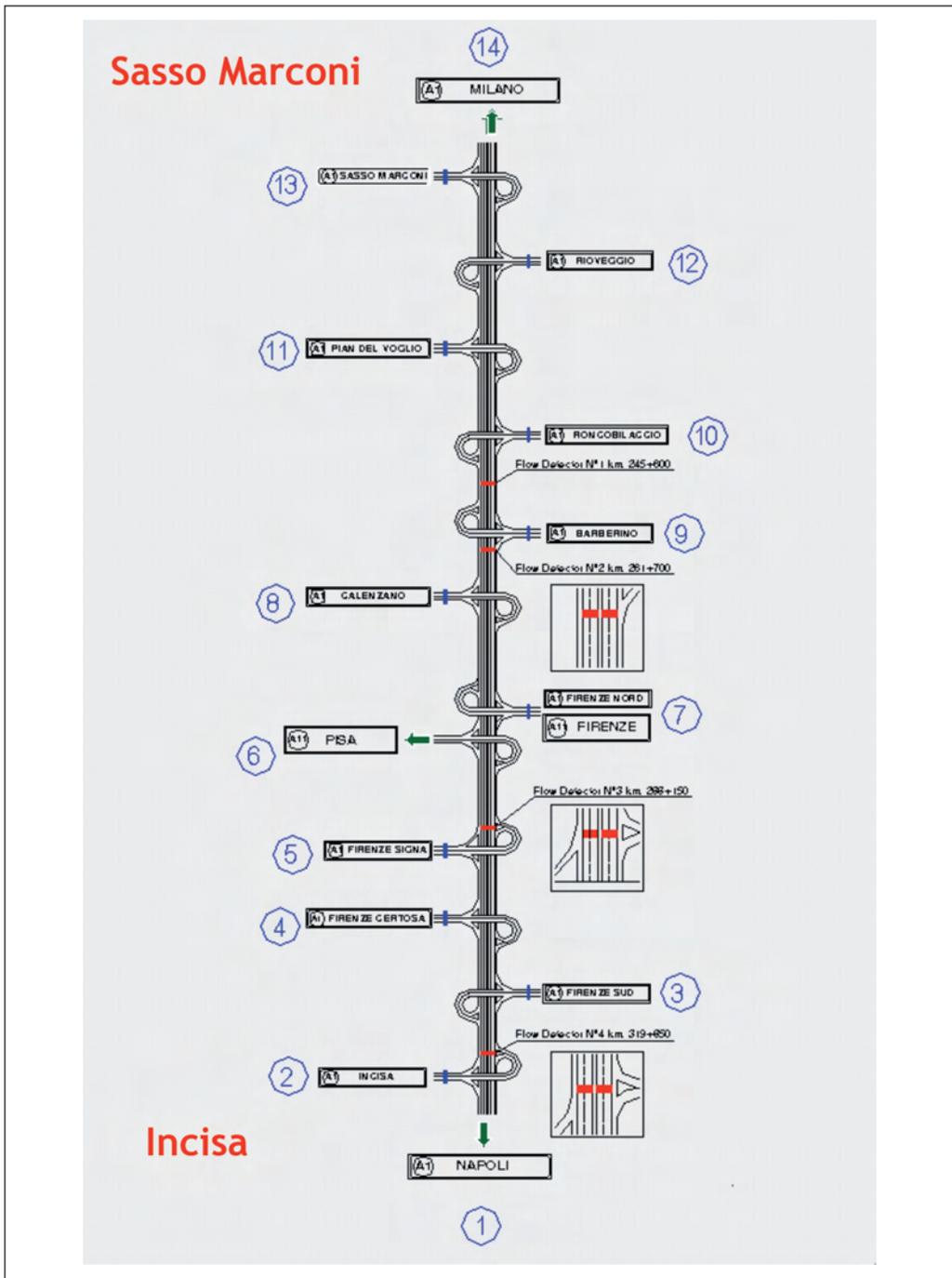
The simulation of individual vehicles whose dynamics are based on detailed car-following models including behavioural variables, enables the analyst to derive estimators that translate traffic conditions into incident risk estimators. Moreover, the possibility of replicating recorded incidents in terms of current traffic conditions when the incident occurred, location and duration of the incident, and incident severity in terms of number of blocked lanes, blocked length, etc. allows the analyst to test off-line the incident management strategies to determine the best option in such circumstances, with the target of minimising negative effects on users both in terms of quality and safety of circulation (i.e. minimise the amount of vehicles trapped in a tunnel after the incident).

These concepts have been applied to the analysis of the safety conditions of the Italian A1 motorway “Bologna-Firenze” reconfiguration project. Specific attention has been drawn in building the microsimulation model to evaluate the ITS devices that will monitor and manage traffic on the new 8 km long main tunnel included in the project, called “Galleria di Base”, located in the motorway stretch in the Appennini Mountains, called “Variante di Valico”.

The study gave interesting results in terms of effects on traffic management of the different ITS systems analyzed and suggested possible follow-up for identifying safety indicators to be provided by microsimulation techniques. The process for model building and calibration, together with main interesting results obtained in the simulation experiments performed, will be described.

4.5.2 The A1 Motorway reconfiguration project from Bologna to Incisa Valdarno

The Motorway from Bologna to Firenze was opened to traffic on December 3rd 1969. Its original section consists of two carriageways, with two lanes plus emergency lane per direction. Inside tunnels its section is reduced to two lanes without emergency. In the stretches characterised by a high slope an additional lane for heavy vehicles takes the place of the emergency lane. In this area the motorway is also characterised by the presence of 12 interchanges, together with many parking areas and refuelling stations (Figure 4.14). The motorway plano-altimetric characteristics are different along the path from Bologna to the South of Firenze. In the Appennini mountains the motorway was



192 Figure 4.14: Existing A1 motorway from Bologna to Incisa Valdarno

designed as a “mountain motorway” with design speed ranging from 80 to 100 km/h. In the metropolitan area of Firenze, the motorway guarantees better performances in terms of higher design speed (110-140 km/h) with less sharp curves and lower longitudinal slopes, apart from the stretches in the hilly areas of Certosa and S. Donato.

At present, after more than 40 years from its original design, due to the ever-increasing traffic flows that characterise this area, the motorway characteristics can no longer guarantee adequate standards compared with modern motorways, both in terms of operative speed and Level of Service. A complex reconfiguration project of the motorway in this area has been therefore undertaken. The solutions adopted to increase the capacity offer of the system are of three types, according to the characteristics of the route:

- the standard solution consists in enlarging the existing two carriageways – from two lanes per direction to three lanes per direction, including a few variations in the geometric characteristics (mainly to increase the radius of the most critical bends where the original value could not maintain adequate standards in terms of speed and safety);
- a second solution, named [3+(2+2)], consists in the construction of a new three lanes carriageway for one direction and operating the existing two lanes carriageways in the other direction;
- a third solution, named [(2+2) + (2+2)], consists in the construction of a new motorway in the Appennini mountains area, in parallel to the existing one. The new motorway (called “A1bis - Variante di Valico”) has a cross section with one carriageway per direction, each with two lanes plus emergency lane. It is characterized by a new layout with updated characteristics, crossing the Appennino mountains at a lower altitude.

The simplified scheme of the new A1-A1bis motorway system is shown in Figure 4.15.

The new configuration brings to a total number of 8 points where the motorway changes its carriageway composition and this brings an added complexity for users: in the sections where two carriageways are available for the same direction, an unusual route choice is required to the users. In the stretches configured [3+(2+2)], only the carriageway on the right side is connected with the interchanges that are present along the path, while in the Appennini mountains area, with the configuration [(2+2)+(2+2)], the choice between one motorway or the other strongly affects the characteristics of the journey. In fact, the A1 is characterised by poor design standards, with the presence of many interchanges to reach some mountain locations between Aglio/Ortaglia and La Quercia, while on the A1bis, where the design standards are higher, users have to run through a 8.7 km long tunnel (the “Galleria di Base”), with many heavy vehicles.

The considerations above clearly point out the fact that the new A1 will be a real complex “motorway system”, where users will have to face many additional decision points, independently from their main route, paying much more attention than in a

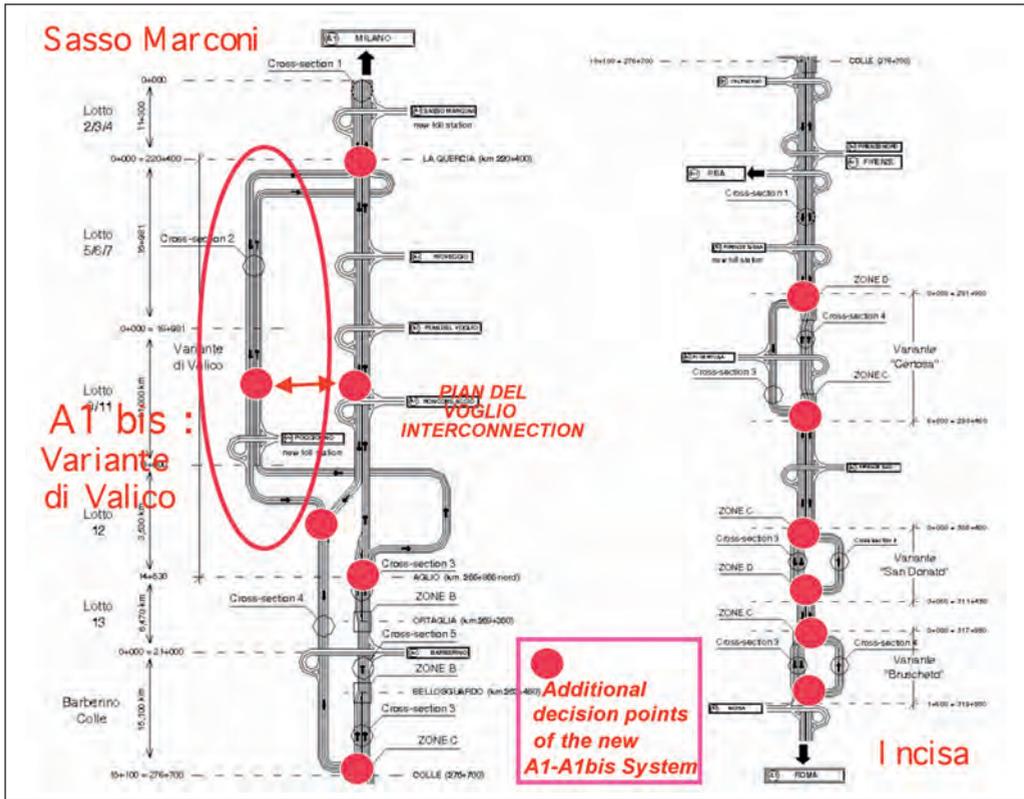


Figure 4.15: The future motorway system A1 – A1bis from Bologna to Incisa Valdarno

normal motorway, with likely moments of indecision. These possible critical situations have to be controlled in order to not affect traffic safety. The availability of more than one carriageway per one direction, on the other hand, can also allow new or more effective traffic management strategies during emergency situations, due for instance, to maintenance workyards, severe incidents, critical weather conditions or particular traffic situations (people moving for holidays, major sport events, etc.). In case of partial or total closure of one carriageway, the presence of two parallel motorways will permit diversion of traffic on the free carriageway, thus delivering a lower decrease in the quality of circulation.

It is believed that a strong role in traffic management can be played in this situation by traffic control and monitoring systems and by well tailored ITS-based user information systems. Given the complexity of the system and the large investment costs required, a detailed study of the operative conditions of the new motorway system was undertaken, based on the powerful performances of modern simulations techniques.

4.5.3 *Dynamic micorsimulation model of the new A1 - A1bis system between Sasso Marconi and Incisa Valdarno*

Construction of the A1 - A1bis system simulation model

In the present study, a microsimulation (or dynamic simulation) technique has been chosen, using the AIMSUN microsimulator (Barcelo et al, 2001). Microscopic traffic simulators are simulation tools that realistically emulate the flow of individual vehicles through a road network. They are proven tools for aiding transportation feasibility studies. This is not only due to their ability to capture the full dynamics of time dependent traffic phenomena, but also because they are capable of using behavioural models that can account for drivers' reactions when exposed to ITS.

In particular, with the current model it has been possible to:

- Accurately represent the given network geometry.
- Have a detailed modelling of the behaviour of individual vehicles. This is achieved by employing sophisticated car-following and lane changing models that take into account both global and local phenomena that can influence each vehicle's behaviour.
- Create an explicit reproduction of traffic control plans. Auxiliary interfacing tools that allow the simulator to work with almost any type of real-time or adaptive signal control systems can also be provided.
- Provide animated 2D and 3D output of the simulation runs. This is not only a highly desirable feature for the presentation of the study but also a strong aid in the analysis and understanding of the operation of the system being studied and can be a powerful way to gain widespread acceptance of complex strategies.

Vehicles can be assigned to routes according to a route choice model. Additionally AIMSUN allows vehicles to change their chosen route from origin to destination according to variations in traffic conditions as they travel through the road network. This provides the basis for heuristic traffic assignment to analyze and evaluate the impacts of management policies based on traffic information provided either by VMS panels or by on-board equipment and any other type of ITS based traffic management tool.

The model creation process required collection of all the data necessary for the model construction and calibration, namely:

- geometric characteristics of the existing motorway and of the new one: plano-altimetric characteristics, transversal sections, design speeds of the different stretches;
- current and future traffic data: hourly traffic flows in the different motorway sections and on/off ramps inside the analysed area, percentage of heavy vehicles, foreseen traffic growth rate to a determined time horizon (2020);
- users behaviour: level of speed limits acceptance (Figure 4.16), reaction to VMS messages, behaviour in queues, in passing and weaving manoeuvres, etc.;
- composition of actual traffic flows: length, speed, dynamic behaviour (braking and accelerating capabilities, guidance acceptance), both for light and heavy vehicles.

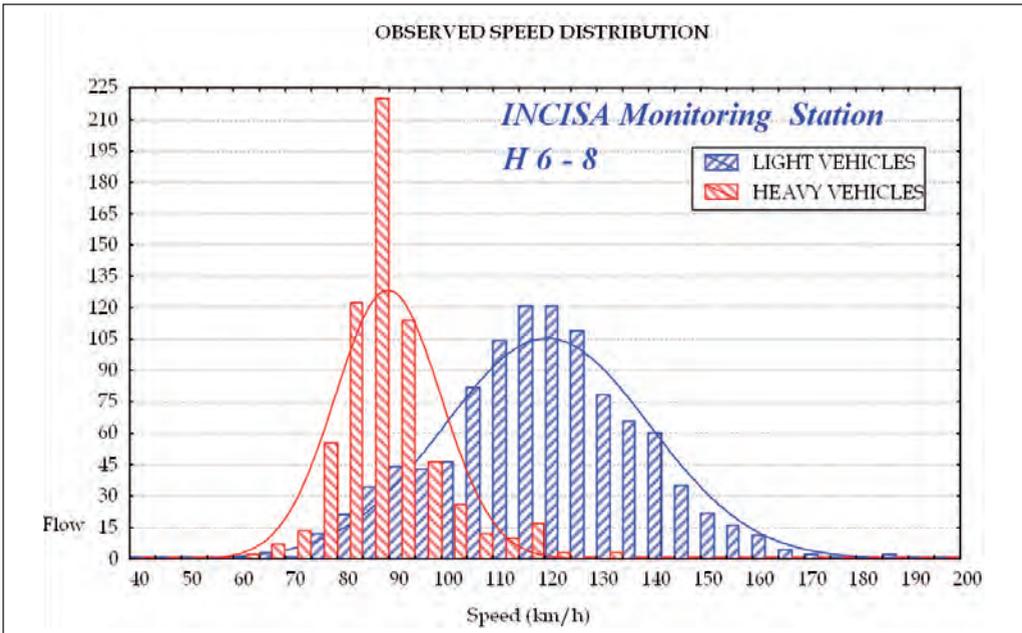


Figure 4.16: Observed actual speeds in two non-peak hours at the traffic monitoring station of Incisa.

Calibration and validation of the model

Once the model has been built a careful calibration and validation activity has been carried out to verify the real correspondence between the model and the observed reality (within the current limits that is a difference of maximum 10-15% between the simulated and the actual values). The obtained results are very good:

- in Figure 4.17, the Barberino off ramp – South direction, the comparison is shown between flows simulated by AIMSUN and observed during the average of three standard week days. The coincidence between the values can clearly be noticed.
- in Figure 4.18, the traffic detector – North direction located at Signa, the hourly traffic flows during a whole day are shown. In this case, the values obtained by AIMSUN are displayed, together with the 3rd and 97th percentile (possible maximum and minimum representative values of traffic flows during a standard week-day). Also in this case we can observe that the line representing simulated flows is included between the maximum and minimum values, thus confirming that the model can represent the real system and its stochastic variations.

Simulation experiments

With the calibrated and validated model, a set of future scenarios have been analysed. They refer to different functioning situations of the future motorway system. Two of them are described below.

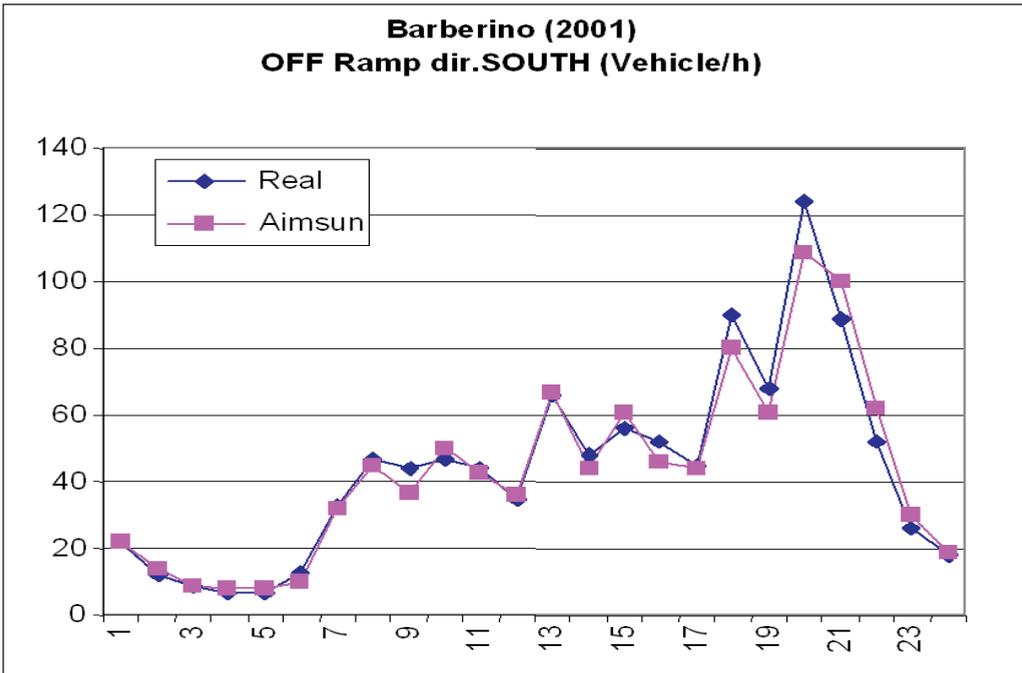


Figure 4.17: Comparison between simulated and observed traffic flows at the Barberino off

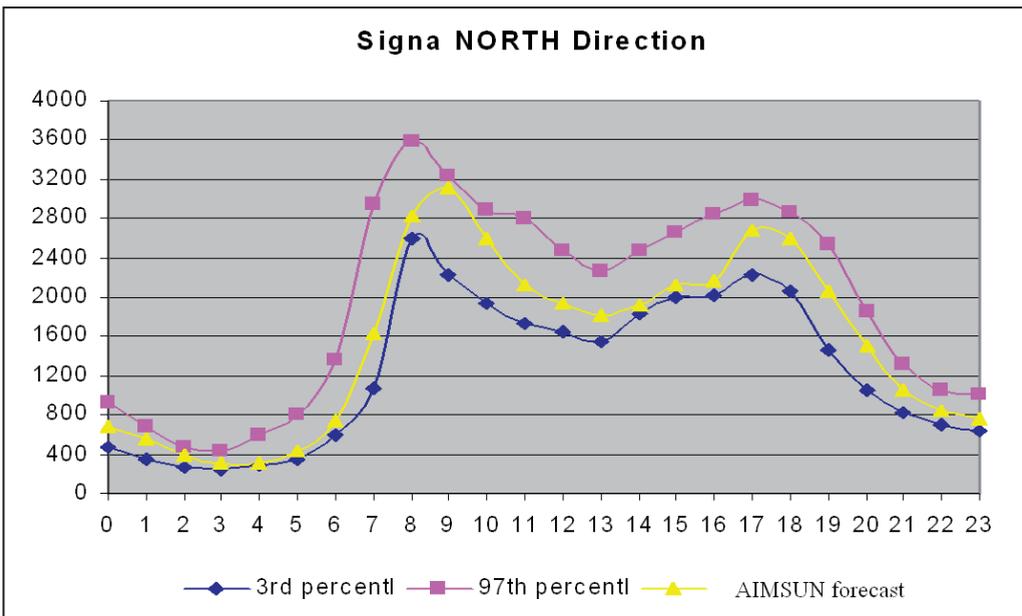


Figure 4.18: Observed hourly traffic flows in North direction at the Signa detector vs. simulated by AIMSUN

(1) Traffic assignment to “A1-A1bis” alternative itineraries

The Variante di Valico project provides for the construction of the new A1bis motorway parallel to the existing A1. This solution was called [(2+2)+(2+2)]. The traffic assignment parameters used in the preliminary design stage were:

- 40% light vehicles and 90% heavy vehicles on the A1bis;
- 60% light vehicles and 10% heavy vehicles on the A1.

This hypothesis was based on the principle of having equivalent level of services on the two parallel motorways. This traffic assignment hypothesis has been verified with the developed microsimulation model. A specific O/D matrix was created and proper mathematical models were utilised providing traffic assignment with the principle of network equilibrium. It minimises the general cost for the trip between each O/D couple, in terms of driving time (that grows together with the increase of traffic on a specific path). The new assignment shows a clear tendency to a higher usage of the new A1bis, given its better geometric standards and its minor length (about 2 Km). This tendency is even more evident for heavy vehicles that are much more affected by road geometric characteristics and in particular by longitudinal slopes. According to the simulation experiments performed, in the North direction, about 55% of light vehicles and 85% of heavy vehicles would take the A1bis in the peak hours, while during non-peak hours these percentages increase to a maximum of 98% and 94% respectively. Accordingly, in the South direction, 45% of light vehicles and 81% of heavy vehicles would take the A1bis, while during non-peak hours these values increase to a maximum of 84% and more than 99%. These results point out that, in service conditions, the A1bis motorway could reach overloaded situations. To avoid this, the users will have to be better informed, at the boundary of the [(2+2)+(2+2)] section, about the actual traffic conditions occurring in the A1bis motorway. The display on the VMS of the trip time in the parallel motorways could help to optimise the use of the system and the information about the actual amount of heavy vehicles inside the 8.7 km long main tunnel of the A1bis could induce the light vehicle drivers to choose the A1 instead of the A1bis motorway.

(2) Traffic management in case of incidents in a tunnel

The second example concerns the dynamic behaviour of the system under emergency situations due to severe incidents that completely block one carriageway for some hours. These situations were analysed taking care of different possible traffic management schemes and a related ITS supervision system (traffic and incident detection, users' information system by means of variable message signs – see Figure 4.19, traffic management system, etc.).

The most relevant analysis regarded the consequences of an incident in the South tube of the main tunnel on the A1bis, the “Galleria di Base” (see Figure 4.20). The

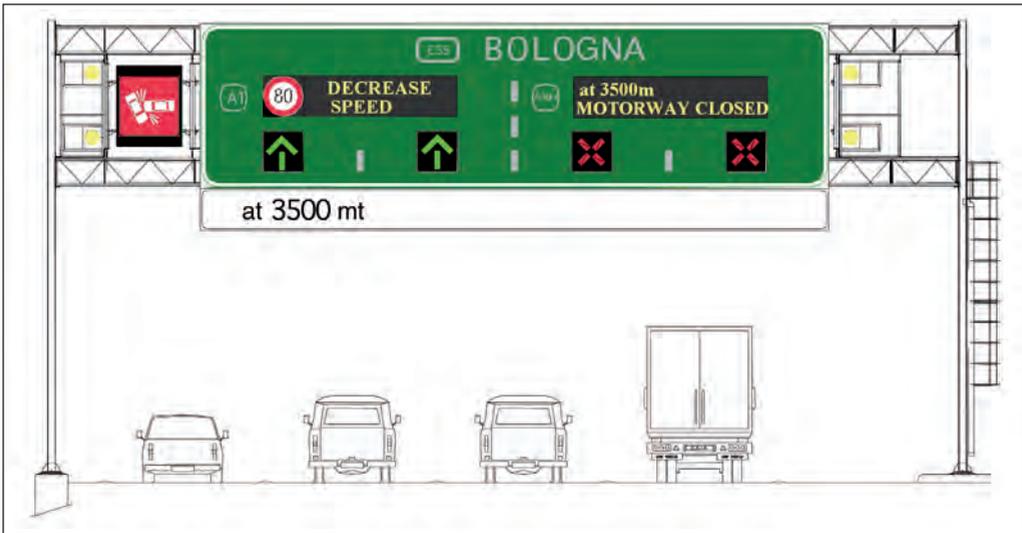


Figure 4.19: Hypothesis of special VMSs with lane access control before the beginning of the A1bis

impact of the possible alternatives for the traffic detection and management systems on the safety procedures foreseen in the emergency plan, together with the architecture of users' information systems, were analysed.

In particular, different incident detection systems and procedures have been analysed:

1. A standard incident detection procedure, based on users phone calls to the control room or activation of SOS alarm posts and verification by Police vehicles reaching the location of the incident;
2. Three Automatic Incident Detection (AID) systems, using different technologies, from a simplified to a very sophisticated and expensive version (called IST1, ITS2 and ITS3).

The differences in the four detection systems mainly consist in the system reaction time when an incident happens and in the incident management phases described hereafter: A = Moment when the incident happens; B = Moment when the incident is detected; B' = Moment when the real severity of the incident is verified; C = Moment when the emergency bypass is open; D = moment when the incident is removed. The ITS3 system is the most technologically advanced and includes cameras every 200-500 metres - according to the HW and SW used and on site conditions - plus dedicated software for the traffic surveillance and analysis. The latter includes algorithms for the incident recognition and the automatic zooming on the danger zone. With this system the central control room can verify the situation almost immediately, long before the emergency teams of the police have reached the incident location.

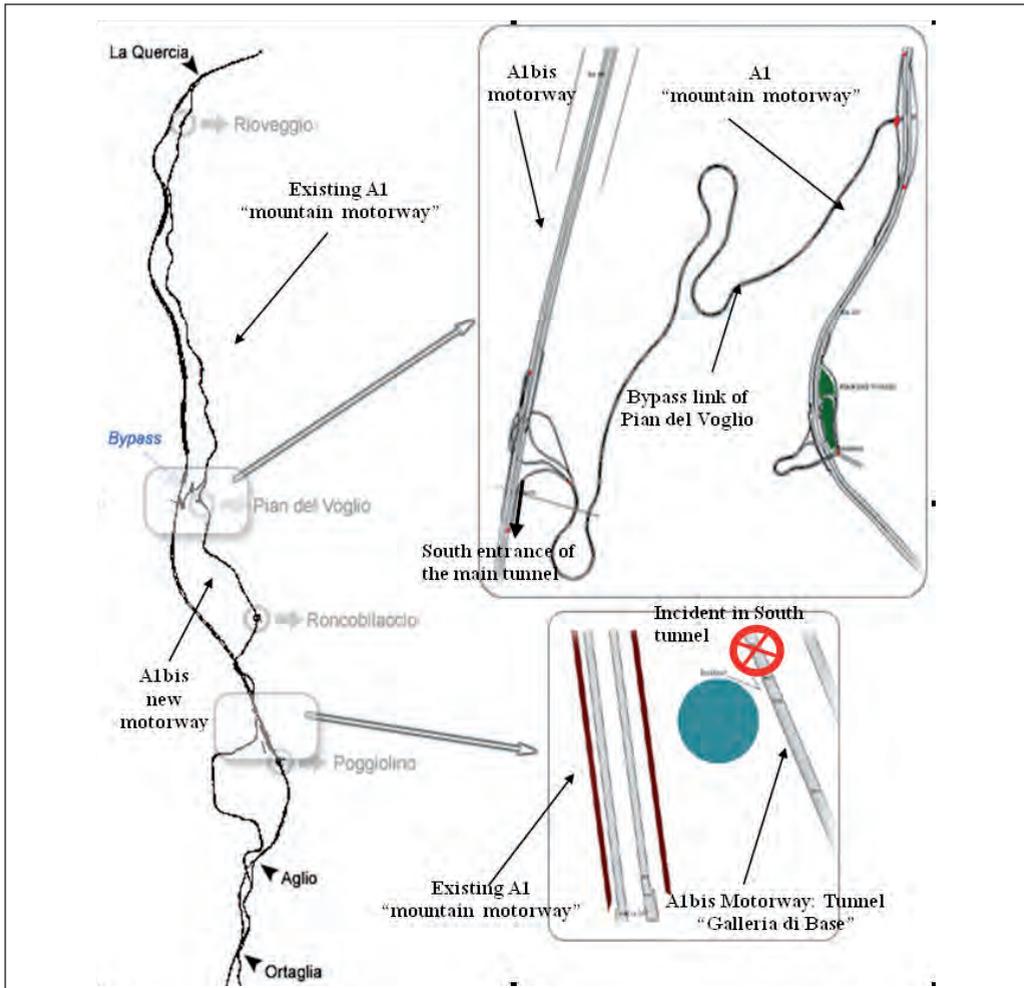


Figure 4.20: Network model for Scenario 4 – Variante 4 (incident in the tunnel “Galleria di Base”)

Management phases	Intervention time (min)			
	Standard traffic control system	ITS1	ITS2	ITS3
A-B	10'	6'	2'	1'
B-B'	20'	5'	3'	2'
B'-C	30'	30'	30'	30'
C-D	constant	constant	constant	constant
Total time A-C	60'	41'	35'	33'

200 Table 4.4: Analysis of traffic management systems performance

In Table 4.4 the main performance of the systems analysed are described. As it can be seen, ITS systems can reduce the intervention time to almost the half, during emergency situations, thus assuming an important role in the reduction of the risk in case of incidents in tunnels. The microsimulation model allowed quantification of the reduction of the exposure time in these situations. In Table 4.5 the number of vehicles potentially blocked inside the tunnel toward the incident location is reported. It is relevant to note that the number of vehicles blocked nearby the incident can be drastically reduced from 246, if a traditional traffic control system is adopted, to 53 with the most sophisticated ITS system.

BLOCKED VEHICLES								
Location	Standard traffic control system		ITS 1		ITS 2		ITS 3	
	Number of vehicles	St. Dev.	Number of vehicles	St. Dev.	Number of vehicles	St. Dev.	Number of vehicles	St. Dev.
Before inc.	94.00	2.55	92.88	2.32	63.75	12.13	33.25	9.98
Metering 8	152.00	15.18	74.00	10.94	16.38	5.27	20.38	9.26
Metering 7	13.75	3.38	17.50	7.65	9.50	5.10	17.00	5.24
Metering 6	12.25	6.44	12.75	6.83	11.50	5.22	13.25	5.87
Metering 5	18.63	9.21	12.88	5.99	17.75	4.82	9.38	4.18
Metering 4	14.38	7.90	12.13	4.46	10.38	6.30	13.50	8.06
Metering 3	11.13	6.90	8.75	3.34	14.38	4.61	14.75	5.49
Metering 2	10.25	3.77	18.13	8.88	17.63	7.00	12.88	7.47
Metering 1	11.75	2.90	12.50	6.10	17.75	10.63	17.50	7.75
Tot.	338.13	22.52	261.50	20.33	179.00	21.78	151.88	21.81

Table 4.5: Number of vehicles potentially blocked inside the tunnel where the incident happens

The snapshots of the microsimulation shown in Figure 4.21 visually help to understand the different resulting situations. They describe the modelling of the main incident management phases in one of the simulation experiments carried out:

- *Snapshot 1* shows the vehicles blocked in front of the incident;
- *Snapshot 2* shows the vehicles stopped by the red lights placed at 900 m intervals along the tunnel, to prevent vehicles from getting closer to the incident location;
- *Snapshot 3* shows the vehicles stopped at the entrance of the tunnel;
- *Snapshot 4* shows the vehicles stopped before the bypass link designed to connect the A1bis to the A1 and vice versa before the entrance of the main tunnel in the A1 bis;
- *Snapshot 5* shows the vehicles directed both to the south and to the north, diverted totally to the A1 motorway due to the closure in both directions of the A1bis main tunnel to allow the emergency procedures to be performed;

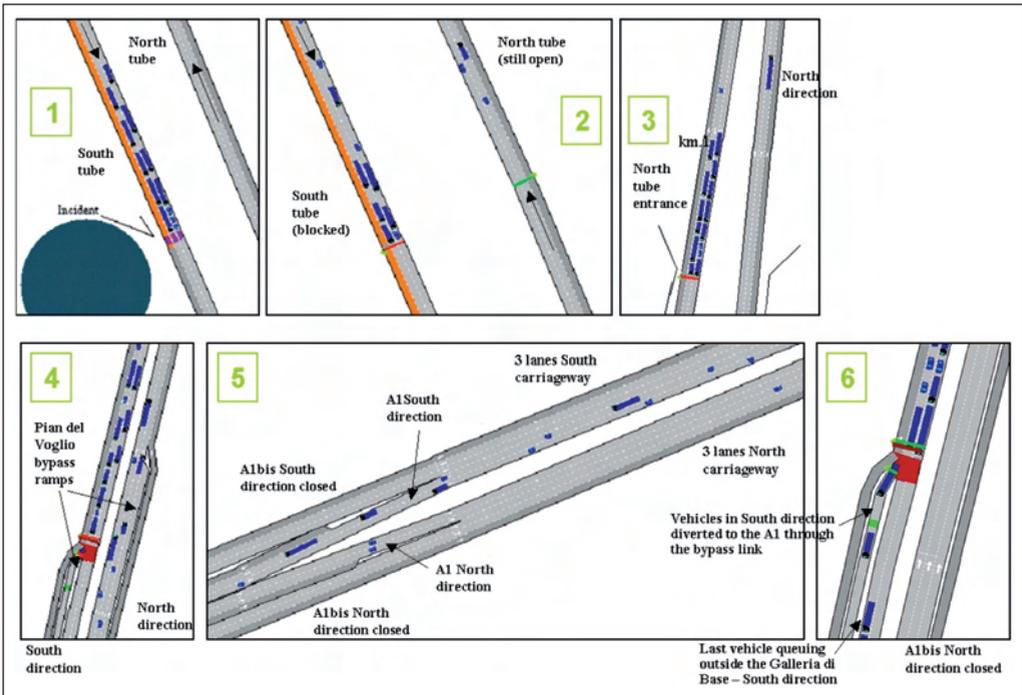


Figure 4.21: Modelling of some of the main incident management phases

- finally, *snapshot 6* shows the vehicles, which were blocked before the bypass, flowing, under police controlled operations, in the by pass link in order to continue their journey while the incident inside the main tunnel is solved.

In Figure 4.22 the length of the queue reached by vehicles inside the tube of the Galleria di Base, where the incident occurs, is shown, while in Figure 4.23 the vehicles potentially blocked outside the tunnel are displayed. The different metering sections where the vehicles queue are those where red traffic lights stop the vehicles when the incident is detected.

The simulations carried out clearly showed that equipping a motorway with a well tailored ITS system offers very interesting features in the traffic managing and controlling activities to fully exploit the flexibility offered by the infrastructure characteristics: the results obtained clearly showed that ITS can reduce the users risk exposure when an incident or a similar emergency situation happens, especially if long tunnels are present along the motorway. Incident management in tunnels is discussed in detail in section 5.4.

4.5.4 Potential indicators for tunnel safety

Taking into account the results discussed above, this section refers to a potential approach to identify safety indicators related to flow variables. For this purpose, micro

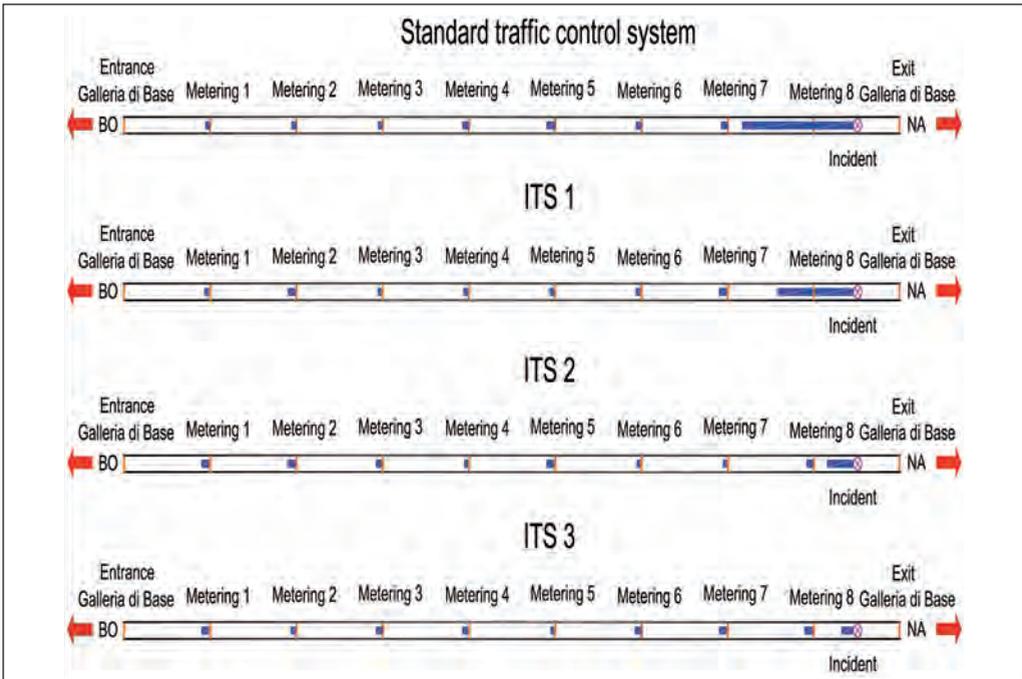


Figure 4.22: Simplified scheme representing the number of vehicles potentially blocked inside the tunnel

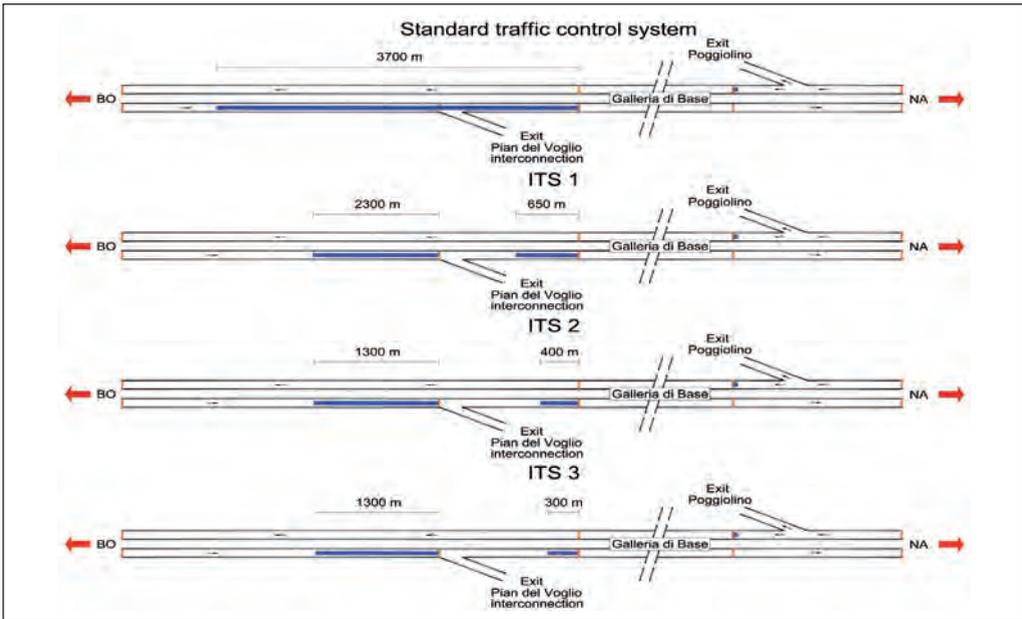


Figure 4.23: Vehicles potentially blocked outside the “Galleria di Base”

simulation techniques can provide a valuable analysis tool to understand the dynamic relationships existing between traffic and safety conditions. They allow identification of the traffic conditions that can potentially bring about unsafe situations, in order to determine the relevant factors in this process and to evaluate their importance in order to plan and adopt specific traffic management strategies that can reduce the risk. Good examples of preventive safety measures and of micro-simulation to assist in their design and evaluation are the advanced traffic management systems proposed for heavy goods vehicles in the tunnels of Saint Gothard in the Swiss Alps (Rapp and Albrecht, 2003) and Vielha in the Spanish Pyrenees (Barceló et al, 2003).

To implement a preventive safety analysis it is necessary to identify safety indicators apt to describe unsafe traffic conditions and to define trigger or alarm values for them, based on statistical safety analysis. In this study different traffic descriptors have been considered and analyzed: spatial and time vehicle headway, speeds and accelerations and their time or spatial variations.

The spatial vehicle headway has been considered at first by the European safety standards for tunnels. A minimum distance of 50 meters for passenger cars and 100 meters between heavy vehicles has been suggested and the safety meaning of such parameters has been considered in a previous paper (Domenichini et al, 2004).

The new European and Italian Directive for the “minimum safety standards in tunnel” refers to vehicles time headway (distance, in seconds, between two consecutive vehicles): its value depends on the relative speed and on the type (light or heavy vehicles) of the consecutive users, on the traffic amount and composition and on the physical road characteristics (longitudinal grade and cross section composition). In a certain moment, the time headway inside the tunnel will be different from point to point. The average time headway represents a statistical representation of the traffic conditions inside the tunnel, related to the value of the average vehicle density. It is a measure of the degree of actual vehicle interaction. When this time value decreases, the risk conditions inside the tunnel are expected to increase because of the reduced safety distances and increased interactions between vehicles. As mentioned above, according to the European Directives the time between consecutive vehicles has to be greater than 2 seconds if there are only passenger cars or greater than 4 seconds between two consecutive heavy vehicles.

The vehicle interaction can also be described by means of the speed profile of each vehicle running inside the tunnel. In free flow conditions the vehicle speed is relatively high and rather constant, because each vehicle runs according to its desired speed. When vehicle density increases, interactions become likely higher and the vehicle speed profile should be characterized by reduced average speed values and increased speed variations. This introduces accelerations and decelerations, whose average absolute value and time variation can thus be assumed to represent traffic conditions characterized by lower or higher risk: the higher the variation the higher the potential risk, and vice versa. It is

assumed that the vehicle densities, which characterise different values of the level of service (LOS) for the traffic flow, can be related to the risk level inherent to each specific traffic flow condition. If this is true, the control of the safety conditions inside the tunnel should be implemented by monitoring the traffic speed and flow, and special control measures should be applied when these values reach alarm thresholds. According to these concepts, microsimulation can permit a preventive analysis of all these values simulating the potential traffic conditions in different situations, such as roads characteristics and/or typology and the performance of the traffic management system. The application of this kind of analysis to a hypothetical road section with standard characteristics is described in the following paragraphs.

The relationships existing between vehicle inter-distances, densities, speed and acceleration profiles have been studied considering a generic 500 m long road segment loaded with variable traffic flows. The results achieved have general validity and can be considered applicable also to tunnels, should the driver behaviour inside a tunnel be considered similar to the one characterising a normal (open air) driving condition. It is believed that the latter hypothesis is not true but studies to differentiate the driver behaviour inside and outside tunnels and to characterize it according to the needs of the microsimulation could not be found in the literature. Specific deepening of this subject is therefore envisaged to increase the reliability of the preventive traffic management procedures in tunnels.

4.5.5 The simulation model implemented

The simulation experiments have been performed using the AIMSUN package.

The geometric characteristics of the considered road segment are:

- carriageway: two lanes plus emergency (motorway type)
- lane width: 3.75 m
- legal speed limit: 130 km/h
- longitudinal slope percentage: 0%
- alignment: straight section

With respect to the traffic demand, the simulations performed have considered different flow conditions ranging from zero to capacity, according to the Highway Capacity Manual (Transportation Research Board, 2000). Two specific percentages of heavy vehicles have been considered, 0% and 50%.

- The parameters related to the users behaviour have been defined with reference to the vehicle type (car and truck) and referred to mean values for the attributes of each vehicle type, their deviations and minimum and maximum values.

During the simulation experiments, data concerning the considered vehicle location and speed have been gathered at every simulation step (equal to 0.75 sec.): for each

specific traffic flow value, the time headway, speed and acceleration profiles have been constructed for a sample of about 180 vehicles. The speed and acceleration variation of each single vehicle has been recorded going through the 500 m long road section considered. Each profile then has been characterized by means of the average value and standard deviation values of the occurred speeds and accelerations.

4.5.6 Simulation results

The results are shown in Figures 4.24 - 4.28. Each diagram shows the relationship between the considered variable and the traffic flow for the two traffic compositions analyzed. They also report the vehicular densities related to each traffic condition in order to allow to show the value of the level of service (LOS), according to the Highway Capacity Manual (Transportation Research Board, 2000), characterizing each of the traffic conditions considered. The latter information is shown by drawing on the plot horizontal lines representing the conventional density limits of each LOS situation (from LOS A to LOS F). The density values are expressed in terms of "passenger cars/km/lane", and derived by the following relation:

$$D = \frac{V_p}{S}$$

where V_p is the hourly flow rate (pc/h/ln) and S is the passenger-car speed. The hourly flow rate reflects the influence of heavy vehicles, the time variation of traffic flow (with PHF), and the characteristics of driver population. These effects are reflected by adjusting hourly volumes (reported in veh/h and derived from the simulation model) using the heavy-vehicle and peak-hour factors.

Figure 4.24 shows the relation between the flow rate V_p , the average time headway and the density when the percentage of heavy vehicles is 0% or 50%. For instance, for a V_p of 500 pc/h/ln which corresponds to a density of 5 pc/h/ln and to a LOS value equal to LOS A, the average time headway assumes a value of about 3.8 seconds if the percentage of heavy vehicles is 0% and 3.4 seconds with a 50% of commercial vehicles in the traffic flow.

Considering a time headway of 2 seconds to identify safe traffic conditions as suggested by the European and Italian Directive, in the specific situation considered, means to refer to a traffic condition characterized by a density of about 900 pc/h/ln, corresponding to the transition between LOS A and LOS B conditions. From this traffic condition, up to the capacity, the spatial time headway between vehicles seems to be independent from the percentage of heavy vehicles, approaching to an asymptotic value of about 1 sec.

Figure 4.25 shows the relation between speed and density under different flow conditions and for the two considered percentages of heavy goods vehicles. For 0% of HV,

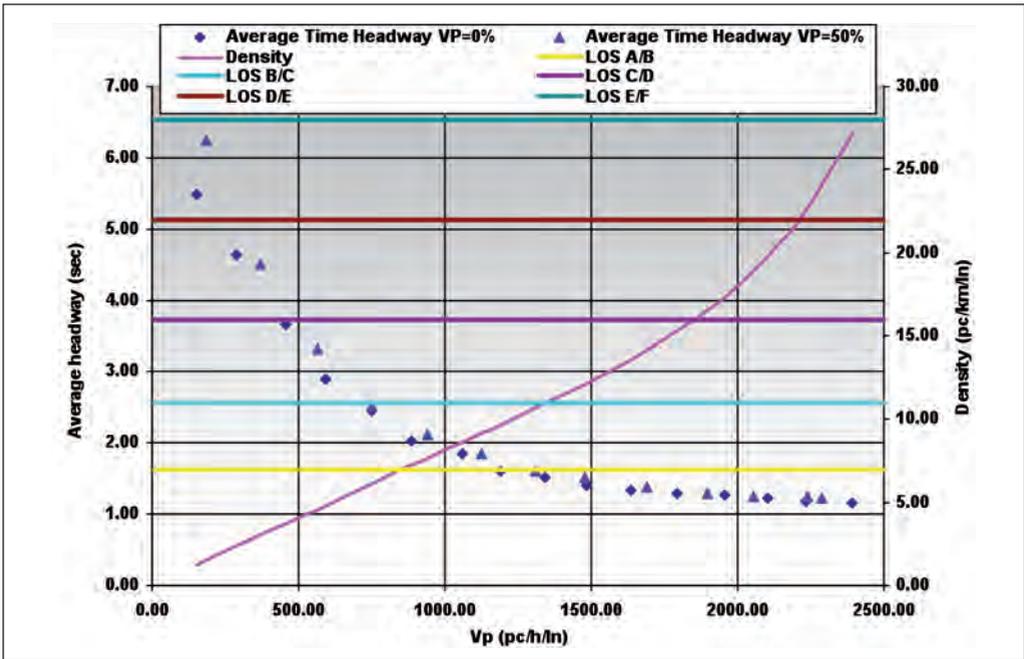


Figure 4.24: Time headway - Flow relation

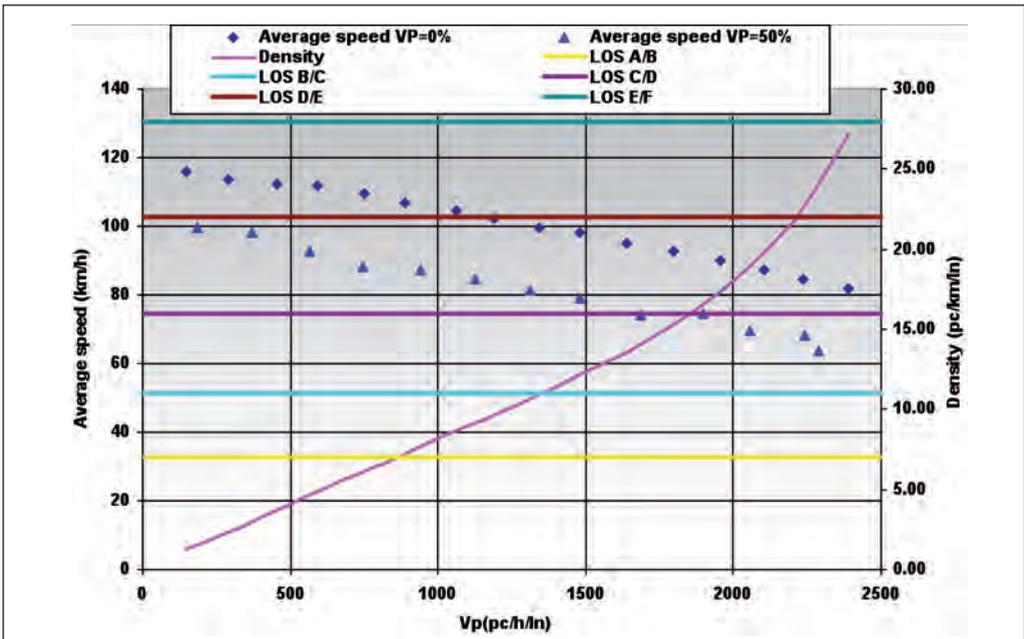


Figure 4.25: Speed-Flow relation

when V_p ranges between 0 and 950 pc/h/ln, the density changes from 0 to 7 pc/km/ln (LOS A) and the average speed assumes values ranging between 115 km/h and 105 km/h; if the percentage of HV is equal to 50%, for the same level of service (in terms of V_p and density) the average speed decreases, assuming values ranging between 100 km/h and 85 km/h.

As it is logical to expect, when the density increases the speed decreases. The presence of commercial vehicles reduces the average speed value, but the decreasing trend remains the same.

For each level of service it has also been possible to define a speed distribution representing the variability of the average speed of the vehicles belonging to the traffic flow of the given entity. Assuming a normal distribution, Figures 4.26 and 4.27 show the obtained density functions, according the relation:

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\left(\frac{(x-\mu)^2}{2\sigma^2}\right)}$$

with μ and σ equal to the mean and standard deviation of the vehicles' speed.

The variability of the average speed operated by the vehicles within each considered traffic conditions reduces when traffic conditions go from LOS A to LOS E. This result was also expected since a reduction in the LOS means an increase of the vehicles interactions and a consequent reduction of freedom in the choice of the operative speed. As it can be observed, they both tend to decrease with the increase in traffic volumes, which could be considered as a factor of increased safety. Thus, the average speed and the speed variability actually do not seem to be good safety indicators. In fact they represent the result of the interactions occurring between the vehicles belonging to the same traffic flow: if the speed value is low (which again could be a good result itself), the desired speed remains the same and the user, obliged to a reduced speed, will try, as soon as the traffic conditions allow it, to accelerate to reach his desired speed, being obliged, later on, to rapidly decelerate when the interaction with the next vehicle occurs. This fact is emphasized if commercial vehicles are present in the traffic mix as it can be deduced comparing Figure 4.26 with Figure 4.27. The speed variability in the vehicular flow is slightly higher if the commercial vehicles are present (HV=50%) and this can result in reduced safety conditions.

On the other hand, the actual level of interactions among vehicles can be derived from the observation of acceleration/deceleration of each vehicle, since these parameters indicate the continuous speed and position adjustment that each user has to perform under high traffic density conditions: when the interaction between vehicles increases, accelerations and decelerations become more frequent. This likely requires a higher driving attention and a higher risk of improper manoeuvres. As mentioned in the previous sections, microsimulation is an ideal world where no real crash can occur, since users

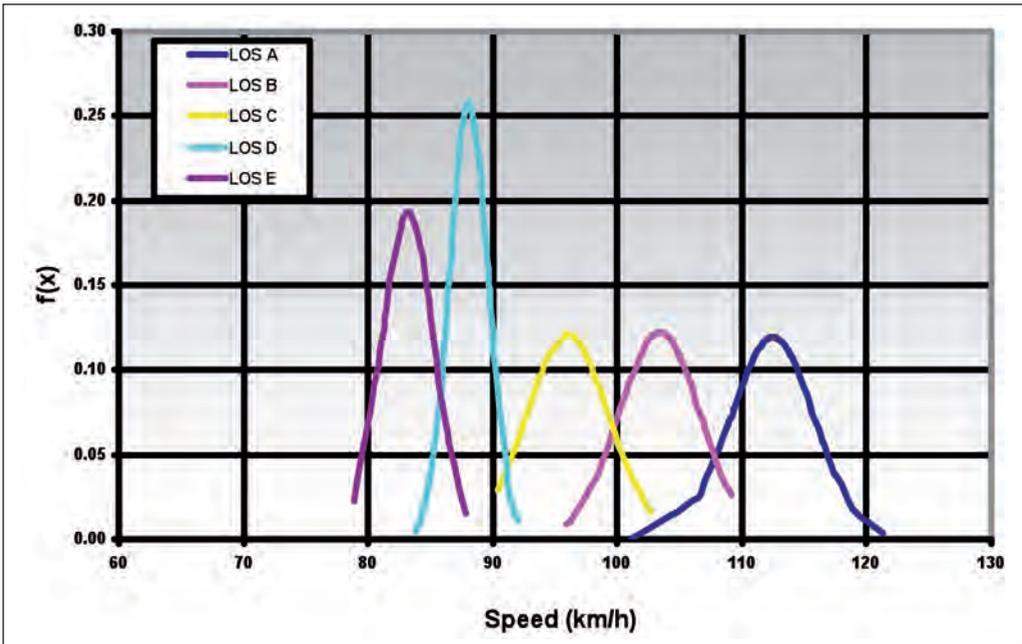


Figure 4.26: Speed distribution (%HV=0)

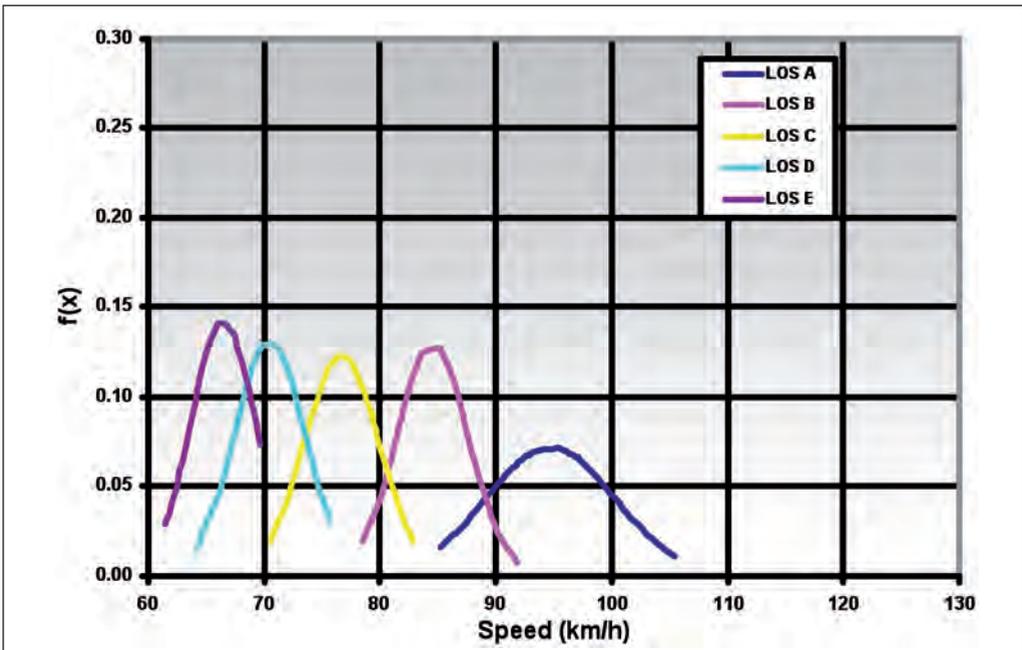


Figure 4.27: Speed distribution (%HV=50)

mistakes can not be represented, but the more frequent are the corrections requested to drivers (acceleration/deceleration), the higher is the risk of a potential error in reality. The different behaviour of the vehicles in the traffic flow can be therefore represented by the average value of the acceleration/deceleration characterizing their path, where a bigger variability of these values can represent an increase of the interaction degree between the vehicles. According to the above considerations, the variation of the accelerations/decelerations could be therefore considered to be a proper safety indicator.

In Figure 4.28 the average standard deviation of acceleration/decelerations of the vehicles, under different flow conditions, has been plotted: the black line represents the interpolation curve for a percentage of heavy vehicles equal to 0; the red line the interpolation curve with a 50% of HV. For HV=0%, while the flow increases, the variation of the acceleration increases up to a maximum value, which is reached when the road segment attains the capacity (in the considered case 2400 pc/h/ln, which corresponds a LOS E); the same relationship has been derived for HV=50%, but the maximum value occurs for a reduced flow rate (1700 pc/h/ln) corresponding to density values between LOS C and LOS D conditions.

The traffic conditions characterized by the higher values of the accelerations/decelerations variability can be considered to be the most unsafe conditions, which for this reason should be avoided inside tunnels. From Figure 4.28 it is possible to define the related critical traffic values (flow rate) and, by considering an adequate safety margin, the related alarm thresholds, above which special traffic control measures should be introduced. These values depend on the traffic mix compositions as suggested by the new EU safety standards for tunnels.

The results obtained allow us to understand the safety margins adopted by the EU standards, as shown in Figure 4.28. From Figure 4.24, the flow values corresponding to the time headways of 2 and 4 seconds have been defined as 900 and 400 pc/h/ln respectively for light and heavy vehicles. Both represent LOS A traffic conditions and are really far from the critical situations identified from Figure 4.28. When dealing with tunnels freely opened to traffic, operating in normal traffic conditions, restricting traffic when $LOS \leq A$ seems very critical. Therefore a reduction of the safety margins adopted by the EU standards, when dealing with this type of tunnels, seems possible as outlined in Figure 4.29. For a traffic mix composition with HV=0% the threshold flow value could be identified in 1250 pc/h/ln corresponding to the transition between LOS B and LOS C conditions and to a time headway of 1.8 sec (see Figure 4.24). For HV=50%, the threshold value reduces to 900 pc/h/ln, corresponding to the time headway of 2 sec.

4.5.7 Conclusions

210 The work reported shows that microsimulators can be a very effective tool to support planners and road designers in their design choices and to verify the effectiveness of their

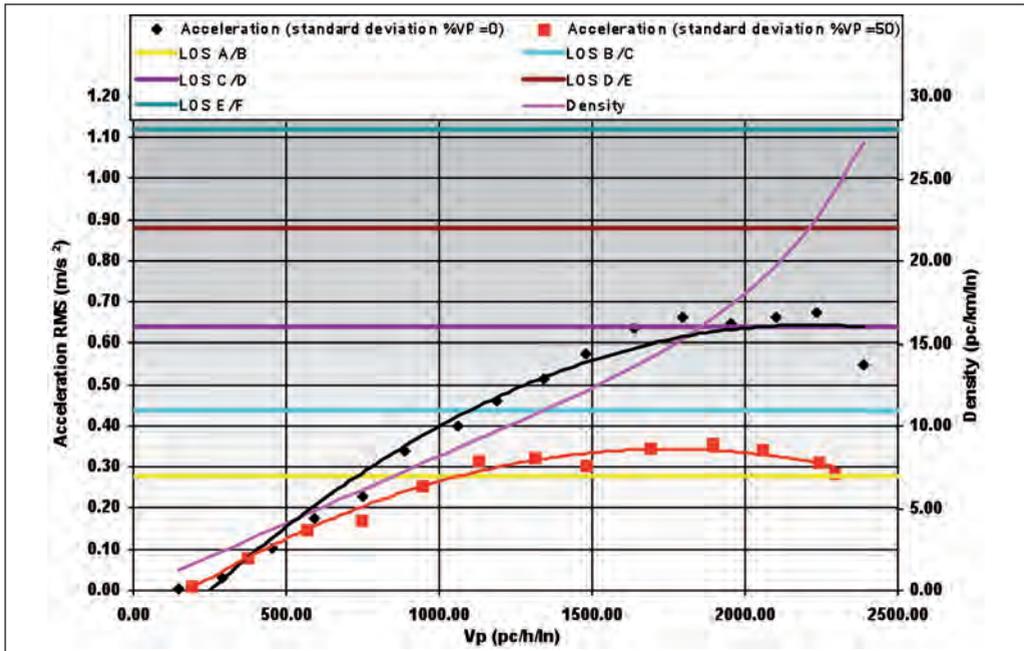


Figure 4.28: Average standard deviation of acceleration

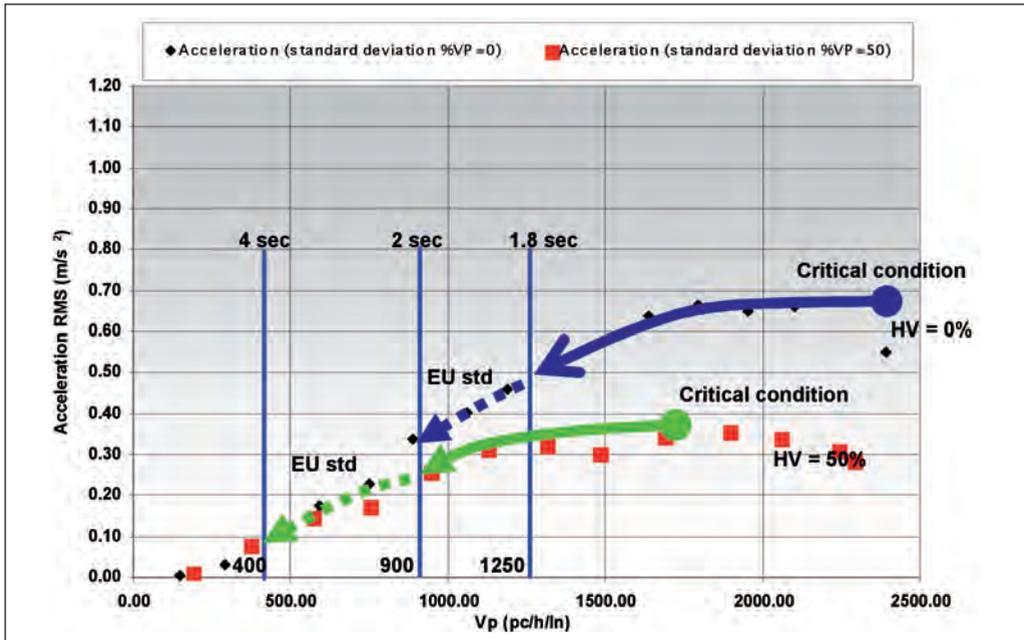


Figure 4.29: Safety thresholds for traffic flows inside tunnels

decisions in all the different traffic conditions and service conditions. They also allow better understanding of the potential of the traffic monitoring and control systems and of the information technologies to be included in the design.

The simulations carried out clearly show that equipping a motorway with a well tailored ITS system offers very interesting features in the traffic managing and controlling activities to fully exploit the flexibility offered by the infrastructure characteristics. They can also provide additional road safety features which can increase the efficiency of the rescue personnel and emergency intervention plans. The results obtained clearly show that ITS can reduce the users risk exposure when an incident or a similar emergency situation happens, especially if long tunnels are present along the motorway.

From the evaluation of the relationships existing between flow, density, speed, time headway and acceleration, threshold values for traffic flow or speed (easy to register) on a section could be established, according to the principle of ensuring average headways higher than the chosen reference minimum value. This approach can be of a very practical usage in designing traffic management schemes targeted to improve safety.

The proposed threshold flow values have been defined considering, as safety indicator, the variability of the accelerations/decelerations of the vehicles included in the traffic stream. The higher is this variability, the higher the interaction between the vehicles. The threshold values depend on the traffic mix composition and could be defined in a value of 1250 pc/h/ln, in case of light vehicles traffic, and of 900 pc/h/ln in case of a percentage of 50% of heavy vehicles present in the traffic mix. These values correspond to vehicle time headway respectively of 1.8 sec. and 2 sec. and are characteristic of traffic conditions characterized by LOS=B.

With respect to tunnels, these values have been compared with those that can be derived from the standards fixed by the European Commission to ensure safety in tunnels. These are expressed in terms of vehicle time headway and are 2 or 4 seconds, depending on the traffic mix. These time intervals, according to the evaluation performed, correspond to flow values respectively equal to 900 and 400 pc/h/ln, corresponding to the traffic conditions characterized by LOS A. The EU standard values are therefore more conservative than the proposed ones but seem less realistic than them.

The proposed approach based on microsimulation and on the indicators derived from it, works at two levels:

- it permits a preventive identification of potential risk situations, when the time headway and the interaction level between vehicles becomes critical for the safety conditions inside the tunnel;
- it represents a tool to plan and design traffic management strategies, capable to control traffic conditions within predefined safety ranges, i.e. to maintain the safety distance below the allowable selected value. With reference to the analyzed case, this can be obtained, for instance, by equipping the infrastructure with a specific ramp metering

system partially preventing the traffic to enter the tunnel, when necessary, therefore using the traffic flow as a derived reference parameter for safety. With the automatic detection of traffic flow (or speed) at the entrance of the tunnel tubes, once the recorded values are reaching the predefined safety threshold values, the ramp metering system could intervene, diverting traffic to a specifically designed traffic storage area constructed next to the tunnel entrance, and allowing the entrance of the vehicle in the tunnel with a predefined cadence, thus increasing the distance between two consecutive vehicles up to safe values and re-establishing safe traffic conditions.

Decision support systems, safety and incident management

5.1 Introduction

This chapter provides a focus for the crucial issues of decision support, safety and incident management. Whilst Authorities are developing initiatives to manage traffic, improve safety and provide a range of services to support mobility, no remedial strategy can be better than the information upon which they have to rely. Section 5.2 addresses this proposition through an overview of the state-of-the-art and the challenges of car-to-car and car-to-infrastructure communications technology, both of which show a strong potential to enhance the capabilities in the field of traffic management operations, infomobility services and safety of road users. The prediction of incident duration on motorways is discussed in Section 5.3 by a review of previous studies on incident duration prediction, exploratory analysis of incident data and the construction and testing of five incident duration prediction models. Finally, a decision support system for traffic incident management in roadway tunnel infrastructure is presented in Section 5.4 (providing material that is complementary to the modelling of safety in tunnels in Section 4.5).

5.2 Emerging Technologies for Car-to-Car and Car-to-Infrastructure Communications

F. Pugliese, G. Valenti

5.2.1 Introduction

Increasing traffic and congestion of public road networks is a growing problem in many countries. Authorities are developing initiatives to manage the traffic, to improve safety 215

and to provide a range of services to support mobility, but no remedial strategy can be better than the information upon which they have to rely. Consequently, the traffic planners need information that is accurate, reliable, timely and complete. The road users too need good quality traffic information in order to plan and adjust their routes. Traffic information has traditionally been collected with local devices, such as inductive-loop detectors embedded in the roads and with video cameras. These fixed installations do not give any traffic information beyond the locations where they are installed, and their coverage is usually confined to congestion-sensitive motorways and a limited number of tunnels, bridges and intersections. The gathering of 'floating-car' data is a totally different concept, whereby a more or less wide percentage of the vehicle population generates real-time traffic information just by participating in the traffic flow.

The greater this percentage, the better the reliability, accuracy and computational capacity of the system, at the cost of a larger amount of calculation resources. The data being collected by the participating vehicles are immediately handled for processing. This approach allows the collection of traffic data across the whole road network – including towns, cities, rural roads and currently unmonitored motorway segments. Floating-car data also has the potential to provide better-quality information. The tracer vehicles can log travel times over a series of road segments, whereas traditional systems measure the traffic only at specific points. In addition, tracer vehicles can detect and report various types of traffic 'events' as they occur. A telecommunications system with suitable coverage and operating at affordable cost is vital to the success of the floating-car concept.

The idea to provide vehicles with smart devices to improve safety, guidance facility and services is supported mainly by a typology of intelligent device-based technology: the on-board sensors, the car to car communication and the car to infrastructure/mobile communications. Each of them provide functionality in a specific area, based on intra-vehicle distance. In particular, if we consider the distance between vehicles, a range of usefulness can be specified about single Intelligent Transportation System (ITS) technologies:

- The on-board systems are used in the range of 0-200 m;
- The Car-to-Car communication (C2CC) systems are mainly useful in the range 0-3000 m, beyond this limit the usefulness begins to decrease;
- The Mobile Communications or Car-to-Infrastructure systems become optimal beyond 3000 m.

The requirements for inter-vehicle (or vehicle-to-vehicle) communications and vehicle-to-infrastructure communications are largely similar, but do have some important differences. The inter-vehicle communications pose some unique problems as the vehicles to which the communications will be directed will only be chosen based on their physical location (in proximity to a given point), rather than through any knowledge of the vehicle's identity. This differs from the vehicle-to-infrastructure communications

which will largely be used to send messages from a vehicle to a fixed network address, or from the infrastructure to an identified vehicle.

These differences are summarised in Figure 5.1. The communications technologies chosen for inclusion in a vehicle networking system also depend on the requirements of the applications to be deployed across the network. These applications will present a number of different requirements on the cost, speed, and availability of the communications.

Inter-vehicle	Vehicle to infrastructure
Dynamic routing	Fixed routing
<i>Ad hoc</i> network	Fixed network
Short medium range	Medium to long range

Figure 5.1: Differences between inter-vehicle and vehicle-to infrastructure communications requirements

Leaving aside consideration of the on-board device and technologies, which don't implement the concept of traffic control, management and guidance, in recent years communication between vehicles has attracted the interest of many researchers around the world (Franz, 2004; Lübke, 2004). In the European Union some research projects have looked into the potential of reducing road fatalities under the eSafety initiative (e.g. GST, PreVent). The same is true in other countries like the USA or Japan. Studies estimate that "about 60% roadway collisions could be avoided if the operator of the vehicle was provided with warning at least one-half second prior to a collision" (Yang et al, 1997).

ITS applications are mainly oriented to safety and services purposes; more precisely we can list:

- Safety: prevention and early detection of crashes or accidents, rescue, management of safety plans, tracking of dangerous goods and special freight;
- Guidance Assistance: automatic help to driving, traffic information, weather information, routing policy;
- Telecom-services: parking availability, hotel, logistic and tourist infrastructure availability;
- Statistics: accident and crashes data collection ;
- Connect-services: email, entertainment, e-commerce, and so on.
- Pricing: Access control and Automatic Fee Collection.

This section is an overview about the state-of-the-art and the pending challenges of car-to-car and car-to-infrastructure communications technology that show a strong potential to enhance the capabilities in the field of traffic management operations, infomobility services and safety of road users.

5.2.2 *Perspectives*

In spite of the huge remaining technological challenges that are to be tackled in the field of ITS, the definition of a sound business case is one of the most critical questions to be solved: Technology allows for a multitude of different telematics services, but the end-users' demands and preferences must be thoroughly investigated to make the market introduction of ITS an economic success. Services and applications which are based on mere inter-vehicle communication and do not involve any infrastructure only provide value to the customer in case a sufficient penetration rate of C2CC-enabled vehicles has been reached. In the case of a road crossing collision warning application that triggers cars to periodically broadcast their exact positions to all neighbours within communication range, for example, a reduction of traffic incidents can only be realized if a high percentage of vehicles approaching the crossings are equipped with a module allowing for transmitting and receiving data. Due to the long vehicle lifecycles, however, a relevant penetration rate can only be reached after several years, even if all newly produced cars were adequately equipped from now on.

For this reason, car manufacturers have to think about gradual market introduction strategies. We therefore do not solely focus on inter-vehicular communications systems here, but also take into account applications that rely on wireless enabled road side units (RSUs), services that leverage common Internet portals. So-called infrastructure-based services (e.g. car-to-home data exchange, car-to-garage communications for remote diagnosis, Floating Car Data or Location Based Services) provide clear customer benefit and motivate drivers to invest in additional wireless equipment for their vehicles. Eventually, after a longer period of time – it is expected that this process will take up to 10 years – high enough penetration rates can be reached to allow for mere inter-vehicular communication services such as intersection collision warning, local danger warning, and the de-central dissemination of real-time traffic flow information. After presenting the state-of-the-art of wireless transmission standards, an overview of both inter-vehicular and vehicle-to-infrastructure communication based services is provided. As will be shown later, the design and provisioning of attractive car-to-car, car-to-environment or car-to-infrastructure services are crucial for the successful market introduction of all this systems.

5.2.3 *Car to Car Communications*

Car-to-car communication (C2CC), often referred to as Vehicular Ad hoc NETWORKS (VANETs), enables many new services for vehicles and creates numerous opportunities for safety improvements. Essentially, C2CC consists of equipped vehicles which communicate with each other, creating a telecommunication ad hoc network. In order to realize this network, special smart devices are provided in each single vehicle. The black-box structure of each component of in-car equipment is schematized in Figure 5.2.

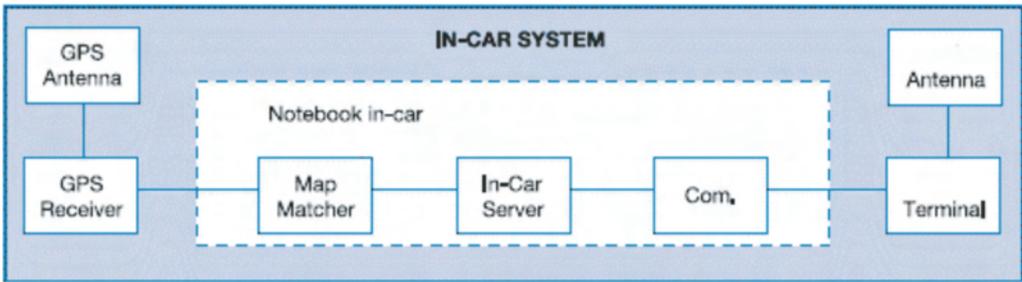


Figure 5.2: Block scheme of single car equipment in C2CC

Each vehicle is equipped with a GPS (Global Positioning System) receiver, a telecommunication module (antenna + terminal) and a processing module (like a “Notebook in-car”). The GPS blocks collect satellite signals to fix the instantaneous position of the vehicle. The map matcher module assigns received signals in a current positioning system of co-ordinates. The telecommunication module provides for collection and forwarding of data from and to other vehicles. The “notebook in-car” is provided by processor(s) and a server which elaborates and stores information; it is the “thinking module” which implements a mesh network between vehicles, manages data and takes decisions and sends suggestions to the driver to realize the ITS purposes of safety and services.

Communication between vehicles can e.g. be used to realize driver support and active safety services like collision warning, up to-date traffic and weather information or active navigation systems. However, besides enabling new services Car-to-Car poses many challenges on technology, protocols, and security which increase the need for research in this field. VANETs have similar characteristics as mobile ad hoc networks, often in the form of multi-hop networks. Due to the high mobility of nodes, network topology changes occur frequently. All nodes share the same channel leading to congestion in very dense networks. The decentralized nature of Car-to-Car leads to the need for new system concepts and information dissemination protocols. In addition, new approaches for data and communication security have to be designed to fit the specific network needs and to guarantee reliable and trustworthy services.

A different approach to Car-to-Car, instead of multi-hop transmission, is to realize a sort of “dispatch rider” transmission, e.g. in the SOTIS (Self Organizing Traffic Information system) project. In this system, vehicles transmit exclusively the results of a traffic analysis and emergency packets, depending on an algorithm of “Receive-Analyze-Send”. Some simulation results (Wischof et al, 2003) show that at least a 10% level of equipped vehicle is needed to reach considerable results, even if 2% of equipped vehicles can assure some benefits in safety and guidance help.

Technologically, a number of more general questions have to be answered. These include decision on the wireless communication standard to be used and message

dissemination schemes capable of exchanging messages in many different network scenarios. Not independent from this, issues like quality of service (QoS) and high speed real-time communication will have to be tackled to enable on-the-fly collision warning or autonomously driving vehicles.

Many different wireless technologies are currently discussed to be used for car-to-car communication. Conventional IEEE 802.11 wireless LAN (WLAN), Dedicated Short Range Communication (DSRC), and GPRS/UMTS are just some selected technologies. Due to its success in the area of data communication, the IEEE 802.11 technology family is most likely to emerge as the prevailing communication standard implemented in future cars, specifically in the variant 802.11p, which is currently defined by an IEEE working group. The European Car-to-Car Communication Consortium (<http://www.car-to-car.org/>) is heavily involved in the standardization process of the IEEE 802.11p automotive communication standard, which is equivalent to the DSRC technologies used in the USA. Both standards use a communication frequency band around 5.9 GHz and rely on the OFDM (Orthogonal Frequency Division Multiplexing) modulation scheme. The preferred medium access method is the so-called random access, which does not need a global scheduler. The IEEE 802.11e standard defines Quality of Service mechanisms for the current WLAN technology. Its concepts can also be used to improve message dissemination in Car-to-Car and improve the channel usage even in combination with the IEEE 802.11p standard. The WLAN-based technology proved to be usable for the general task of exchanging messages between vehicles in an ad hoc fashion, however, for services with specific quality or time constraints, as well as for very large networks (»500 nodes) this technology is not applicable as it is (Gupta and Kumar, 2000).

Moreover, many other different aspects of car-to-car communication still need ideas and results from research. They include high performance and efficient physical layer transmission schemes, fair and scalable medium access (MAC) schemes, efficient data dissemination protocols, security, routing protocols, to name the most critical ones. The term scalability means that the number of users and/or the traffic volume can be increased with reasonably small performance degradation or even network outage and without changing the system components and protocols. Especially due to the distributed nature of car-to-car networks (multi-hop communication) the complexity of protocols for routing or message dissemination is rather high. Using security mechanisms further increases this overhead and the protocol complexity. Unfortunately, the network capacity in multi-hop networks is rather limited (Gupta and Kumar, 2000). Moreover, in large networks a multitude of events will be generated and sent across the network, resulting in a network overload or even complete breakdown (Ni et al, 1999). Hence, better routing protocols and strategies have to be developed to tackle the scalability issue in Car-to-Car of which the routing protocols relying on position information, the so-called geo-routing protocols, are promising.

The use and integration of security mechanisms for warning messages and safety services is absolutely necessary within VANETs (Hubaux et al, 2004). Car-to-car communication and its services will only be a success and accepted by customers if a high level of reliability and security can be provided. The most crucial security service for Car-to-Car is the introduction of trust and the provisioning of trustworthy services. However, this is a great challenge for the distributed VANET. Conventional cryptographic mechanisms rely on e.g. a public key infrastructure (PKI) which is a centrally organized trust scheme. Thus, the use of a PKI in a distributed network is not feasible without new concepts and mechanisms. Especially the exchange and management of certificates in Car-to-Car networks is a challenging task. Besides the introduction and management of trust the reliability of message content is also a big issue for car-to-car communication. The content of a received message has to be verified within a short time to be able to use the information as soon as possible. Since vehicles will encounter each other maybe only once in their lifetime certificate-based reliability is not very efficient. New schemes based on reputation of nodes or even messages will have to be defined to solve this issue. Since most security schemes include some cryptographic calculations the latency will be increased, thus limiting the speed for data exchange. Moreover, if a key agreement needs to be done further delay will be added. Depending on the operations, an additional delay of around 50 ms will be added for each node due to the cryptographic mechanisms.

Since no global scheduling scheme is likely to be used in future car-to-car communication schemes, high speed communication with guaranteed low latency times is a great challenge. Especially for direct back-to-back collision warning very low latency times are required. A vehicle travelling at a speed of 50 km/h travels around 1.4 m/100ms. Hard deadlines are necessary for specific services. However, these quality-of-service requirements are hard to be met in a best effort-based network.

Best effort delivery describes a network service in which the network does not provide any guarantees that data are delivered or that a user is given a guaranteed quality of service level or a certain priority. In a best effort network all users obtain best effort service, meaning that they obtain unspecified variable bit rate and delivery time, depending on the current traffic load. By removing features such as recovery of lost or corrupted data and pre-allocation of resources, the network operates more efficiently, and the network nodes are inexpensive. In C2CC, therefore, new approaches have to be defined to fulfil these requirements.

Other different frequency bands can be used in Inter Vehicle Communications. Bluetooth and Ultra-Wideband (UWB) technologies are explored in some detail. It is possible for communicating vehicles to use both infrared and radio waves. VHF (Very High Frequency) and microwaves are a type of broadcast communication while infrared and millimetre waves are a type of directional communication. Microwaves are used most often. It is possible to use Bluetooth, which operates in the 2.4 GHz industry, science,

and medicine (ISM) band, to set up the communication between two vehicles. It is reliable up to a speed of 80 km/h and range of 80 m. However, it can take up to 3 seconds to establish the communication. Also, since Bluetooth requires a master and slave setup, the master could potentially refuse a communication request. In addition, the master may already be communicating with another slave, which would lower the possible communication rate. An alternative to Bluetooth is a new radio frequency technique called UWB. Because of the wideband nature of the signal, UWB has been used in radar applications. The Federal Communication Commission (FCC) in USA refers to UWB technology as having high values of fractional bandwidth (> 0.25). The main advantages of UWB technology are its high data rate, low cost, and immunity to interference. On the other hand, it could possibly interfere with other existing radio services, for instance, the GPS. The system is not believed to be too sensitive to multipath or jitter effects. The fact that UWB could potentially interfere with communication sources is a technical problem that must be solved before it could be used in Inter Vehicle Communications systems. Also, there is a concern that UWB's radio coverage could extend to uninvolved vehicles, which could generate false or irrelevant information.

5.2.4 Car to Infrastructure Communications and Mobile Communications

The second important area of interest is the services and applications enabled through Car-to-Infrastructure and Mobile communication. In this scenario the basic idea is to provide services and traffic management by communicating data to and from a centralized structure via wireless communication systems which can be proprietary infrastructure or public ones (e.g., cellular phone network). It is worth remarking that in Car-to-Infrastructure solutions, the information handling and processing can be done in centralized servers located outside vehicles. In order to increase the efficiency and safety of the traffic, new concepts and technologies for a future Integrated Road Transport Environment (IRTE) have been developed and implemented in various national and international Research & Development Programmes (e.g. DRIVE II/Europe and IVHS/North America, Intelligent Vehicle Highway Systems). As mentioned above, the roadside communication structure can be mainly of two types: proprietary or public. The public communication system is mainly one of the cellular phone networks; other public communication systems are based on FM radio broadcasting, as the TMC (Traffic Message Channel).

Traffic Message Channel (TMC) is a technology for delivering traffic and travel information to drivers. It is typically digitally coded using the FM-RDS (Radio data System) on conventional FM radio broadcasts. It can also be transmitted on DAB (Digital Audio Broadcasting) or satellite radio. It allows silent delivery of high quality accurate, timely and relevant information, in the language chosen by the user and without interrupting normal services. Both public and commercial services are now operational in many European countries. When data are integrated directly into a navigation system, this gives

the driver the option to take alternative routes to avoid traffic incidents. The following countries provide a TMC service: Australia, Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Italy, The Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, United States of America. It is also planned in Portugal and Turkey.

Autonomous in-car navigation systems (possibly extended with RDS-TMC) are becoming more and more available. Although these systems provide the car drivers with much useful guidance information, one of their main disadvantages is the restriction in providing the real up-to-the-minute (traffic) situation. A standalone autonomous system is by definition not better informed than its digital map. The RDS-TMC extension overcomes this problem partially, but offers only a very restricted bandwidth for the unidirectional FM broadcast-based communication. Thus communication systems at the roadside, such as digital cellular radio systems, originally introduced for mobile speech communication purposes, offer a mighty opportunity to change, in a relatively simple way, the autonomous in-car navigation systems into a full-fledged dynamic route guidance system.

Such a system receives all the information, required for an optimal use from the outside world via the data down-link of the cellular radio system. On the other hand the system is able to communicate with the outside world via the data up-link (Weling, Jonsson and Demery, 1991). Based on these considerations research and development plans have been stimulated actively by the European Union, e.g. the DRIVE (Dedicated Road Infrastructure for Vehicle safety in Europe) Programme of the (then) Directorate General XIII (e.g. the SOCRATES project (System Of Cellular Radio for Traffic Efficiency and Safety)).

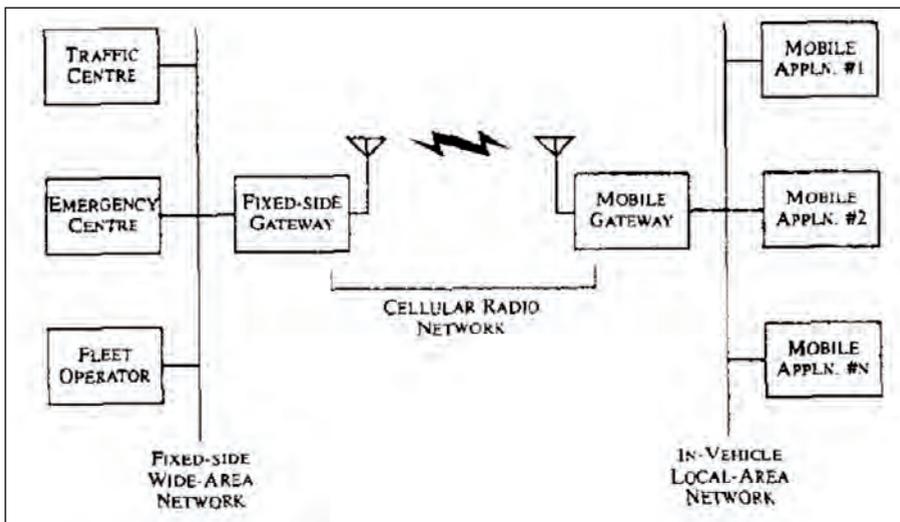


Figure 5.3 The SOCRATES reference architecture (Source: Zijderhand and Biesterbos, 1994)

Figure 5.3 shows a diagram representing the SOCRATES reference architecture (Demery et al, 1994). In this diagram the three parts forming the SOCRATES configuration can be clearly distinguished:

- the fixed side where the various centres (for traffic control as well as for supplying information) are situated;
- the in-vehicle mobile side where the applications run; and
- the communication link between these two via a cellular radio network.

The diagram is symmetrical in the sense that both sides contain a gateway connecting the information centres at the fixed side and the mobile applications at the vehicle side to the communication network.

The Vehicle to Infrastructure system based on a public cellular network system is designed to interface with various mobile networks (GSM/GPRS, the pan-European mobile communication standard), that is the preferred network because of its future opportunities and its almost global coverage. The typical Vehicle to Infrastructure system, such as the SOCRATES in-vehicle system, consists of the following parts:

- 1) an in-car navigation system composed of:
 - a navigation computer in combination with an electronic compass, wheel sensors and a digital map stored on CD ROM,
 - an MMI (man machine interface) computer with a keyboard for interfacing between the driver and the system, in combination with a display and loudspeakers for providing the driver with information on navigation,
 - a GPS system, the satellite based global positioning system;
- 2) a (digital) car telephone with data facility; and
- 3) a so-called application gateway (AGW) which connects the navigation hardware to the mobile telephone.

As it is one of the basic principles of SOCRATES to utilize existing networks as much as possible, one of the DRIVE trials in Germany was based on the current status of the D1 GSM mobile phone network. This means that GSM for the trial only supported connection-oriented services. The participating cars were called once every 5 minutes in order to make connection with the navigation computer and to download new dynamic information. However, as realistic traffic information has more of a “bursty” character, it is recognised that the preferred type of service has to be based on a packet mode. For this reason the project community has preferred the definition of a General Packet Radio Service (GPRS) use on GSM. This idea is accepted by ETSI (European Telecommunication Standards Institute). Proprietary infrastructure support a different approach in exchanging data and services, as discussed below.

Vehicle-beacon communication systems are expected to be an important element of the IRTE, since they provide a highly reliable, mobile communication link between

vehicles and roadside infrastructure at high data rates in free traffic flow. Typical Road Transport Informatics (RTI) services, which need to distribute or collect data in a local environment, are: e.g. automatic toll debiting/automatic fee collection (AFC), dynamic route guidance (DRG), fleet management (FM), access control (AC) and parking management (PM). To make the investment of an IRTE built up by vehicle-roadside communication systems most beneficial, an optimal use of the system capacity can be achieved by offering several services at the same beacon site. Furthermore, the user acceptance of newly introduced mandatory road pricing systems can be raised by combining them with additional services, which provide the driver with information about the current traffic situation and help him to find the optimal and safest route to his destination (such as Dynamic Route Guidance/Emergency Warning). In order to avoid interference between services, priorities can be assigned to different services. For the development of high-performance communication protocols and the optimal selection of system components a number of requirements and constraints resulting from different applications and system environments have to be taken into account: e.g. the amount of data to be transmitted (data packets from 50 bits up to several hundred kbits) and the required reliability (for automatic fee collection a transaction error rate of 10^{-6} is required) vary considerably for different applications. The system environment has a strong influence on the characteristics of the traffic flow (intensities, headway and speed distributions) as well as on the quality of the physical channel: an automatic fee collection system on a motorway has to cope with high traffic intensities and sometimes extremely high speeds, whereas in an urban environment the vehicle speeds are relatively low, but multi-path fading effects due to reflections of buildings, traffic signs, parking vehicles etc. may lead to a considerable reduction of the channel quality.

The operators of vehicle-roadside communication systems require so-called multi-lane systems, which allow vehicles to pass a beacon site without any restriction (no reduction of vehicle speeds, lane changing and overtaking possible etc.) and which enable fast installation (minimal road work, no physical barriers). In order to realize efficient and reliable multiple access in a multi-lane vehicle-beacon system, the interference between vehicles, which need to communicate at the same time, has to be reduced to a minimum. System configurations using different access techniques have been proposed (see Figure 5.4) in order to separate up link transmissions from each other. The Space Division Multiple Access SDMA approach (see Figure 5.4/I) makes use of antennas with very narrow beams, which are able to provide a lane-specific and very reliable uplink communication zone. Therefore parallel transmissions by vehicles in different communication zones can be received by the beacon. In order to avoid interference effects from adjacent communication zones, the total available bandwidth often has to be divided into different frequency bands on the uplink, which reduces the available up-link data rate of each zone. Using a Random Time Division Multiple Access (RTDMA) approach,

one communication zone is provided for all lanes (see Figure 5.4/II) and multi-access interference has to be reduced to a minimum by using suitable medium access control protocols, which are able to avoid or resolve data collisions. Shadowing effects, which are caused by vehicles, as well as effects caused by multi-path fading, can be reduced by optimized antenna configurations using diversity techniques (e.g. space diversity, see Figure 5.4/III).

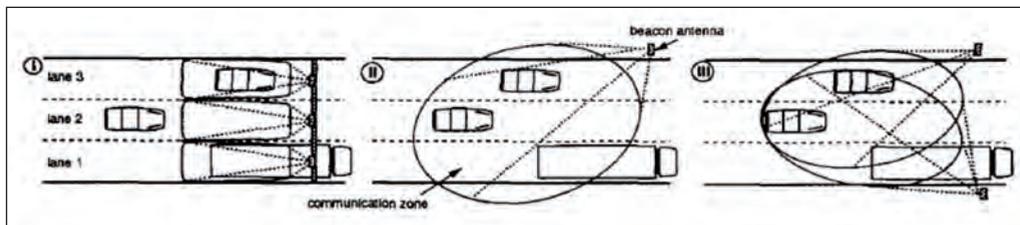


Figure 5.4: Different system configurations (Source: Wietfeld and Rokitsansky, 1994)

Since a continent-wide introduction of RTI-systems is envisaged, the need for standardized protocols and interfaces has been recognized in an early stage of the development. A basic requirement is that the protocols have to be adaptable to different system configurations and application processes. Two approaches, a synchronous protocol, proposed for the IVHS communication architecture, (Kady and Ristenblatt, 1993) and an asynchronous protocol, which is proposed as European standard CEN TC 278 WG 9 (Rokitsansky and Wietfeld, 1993), has been presented.

The asynchronous European protocol is based on a half-duplex TDMA approach. A number of different schemes have been developed and evaluated such as random delay counter, persistence mechanism, single/multi-slots and channel sensing (Rokitsansky and Wietfeld, 1993). The synchronous protocol proposed for the IVHS communication architecture, in contrast to the European approach, is a TDMA protocol based on a fixed frame structure.

As an example of the main services that can be provided by the Car to Infrastructure Communication systems, one can consider Automatic Fee Collection (AFC) Dynamic Route Guidance (DRG) which can also be used in a combination of different services at one beacon site. With the (AFC) application, a specific amount of money has to be collected from all vehicles in return for the usage of the road. In an interactive dialogue, which is initiated by the beacon, information related to the authentication procedure, vehicle classification, amount of money to be paid, etc. is exchanged. The DRG application distributes information from regional traffic centres about the current traffic situation in a broadcast message (INFO message) by the beacon in order to allow the driver or on-board equipment to find the optimal route to his destination. To determine the traffic situation the regional traffic centre relies on information about the travel times of vehicles, which are therefore transmitted to the beacon.

Some micro-simulation analyses have been carried out to evaluate protocol performances; the results show that the asynchronous protocol seems to be more flexible and adaptable to achieve a high performance in the case of a single-application beacon (Wietfeld and Rokitansky, 1994). In the multi-application scenario the asynchronous protocol has proved to be a flexible solution to provide a reliable communication link. It can be seen from the results produced that a system which may be installed in the first place to collect fees may also be used to provide additional services with a satisfactory performance with only little reduction of the performance on the AFC application (Wietfeld and Rokitansky, 1994).

5.2.5 Conclusions

Car-to-Car and Car-to-Infrastructure communications are interesting and challenging new fields in ITS and communication network research. While many creative and powerful new solutions have already been proposed, many open issues still exist. In addition to technical breakthroughs, the phase of market introduction is critical for the success of this new technology. These new solutions will only become a commercial and technological success as long as its services and capabilities are of high value to potential users during all phases of the introduction phase. Hence, services and technology have to be adaptable to the different levels of market penetration. Particularly, Quality of Service (especially concerning latency) and security for VANET systems are crucial aspects of car-to-car communication that need to be integrated to ensure the success of this promising technology.

5.3 A comparative study of models for incident duration prediction

G. Valenti, M. Lelli, D. Cucina

5.3.1 Introduction

When an incident occurs, the timely estimate of its duration assumes a key role in the overall incident management process. Specifically reliable incident duration prediction can help traffic managers in providing correct and essential information to road users, applying appropriate traffic control measures at or near the incident location and evaluating the effectiveness of the incident management strategies that are implemented. In current practice, rough incident duration estimates are provided by traffic operators or police on the basis of experience and the known characteristics of the incidents such as the nature of the incident, the occurrence of injuries and fatalities, as well as the type and number of vehicles involved. The reliability of these practices is still unknown and largely depends upon the skill and experience of the operator.

Grounded on the existing scientific literature, this study intends to develop and compare the effectiveness of different prediction models suitable to estimate the incident duration in a real-time environment. The proposed prediction models incorporate variables that have the greatest influence on the incident duration and that can be practically obtained in real-time as soon as the incident is detected and verified. The incident data used in this study for developing and testing the prediction models have been supplied by the “Fiano” Trunk Management Centre of Autostrade per l’Italia Spa which is the biggest Italian motorway company. These data, usually obtained from the incident scene and manually logged by the operators in a database, contain information about the incident characteristics, the personnel and equipment involved to clear the incident and the related response times, including the beginning and ending time of the incident. First, a statistical analysis of these incident data was conducted to investigate the factors that influence the incident duration with the scope to find out what variables are important for the prediction process. Both the ANOVA and Kruskal-Wallis analysis have been performed to measure and test the statistical significance of differences in incident duration for each of the explanatory variables. Then, different predictive models, ranging from parametric (polynomial-type) models, to non-parametric and neural network models, have been considered and compared to evaluate their capacity of predicting the test data.

This section is organized as follows: a review of previous studies on incident duration prediction, aimed at obtaining insight in to the strength and weakness of the many methods that have been developed up to now, is presented below. This is followed by the exploratory analysis of incident data collected by “Autostrade per l’Italia Spa” to identify critical variables associated with the incident duration. Next the construction and testing of five incident duration prediction models are reported, namely: Multiple Linear Regression (MLN), Prediction/Decision tree (DT), Artificial Neural Network (ANN), Support/Relevance Vector Machine (RVM) and K-Nearest-Neighbour (kNN). Finally, some practical conclusions are drawn from the comparison of the predictive accuracy of the suggested models.

Previous studies on incident duration prediction

Incident duration is the time elapsed from the incident occurrence until all evidence of the incident has been removed from the incident scene. Incident duration consists of three stages: Reporting, Response and Clearance time (Figure 5.5). Reporting is the time between the incident occurrence and the determination of the precise location and nature of the incident. Response is the time needed to dispatch the appropriate rescue personnel and equipment to the incident site. Finally, Clearance is the period of time between the arrival of response units and the restoring of roadway capacity to its pre-incident condition.

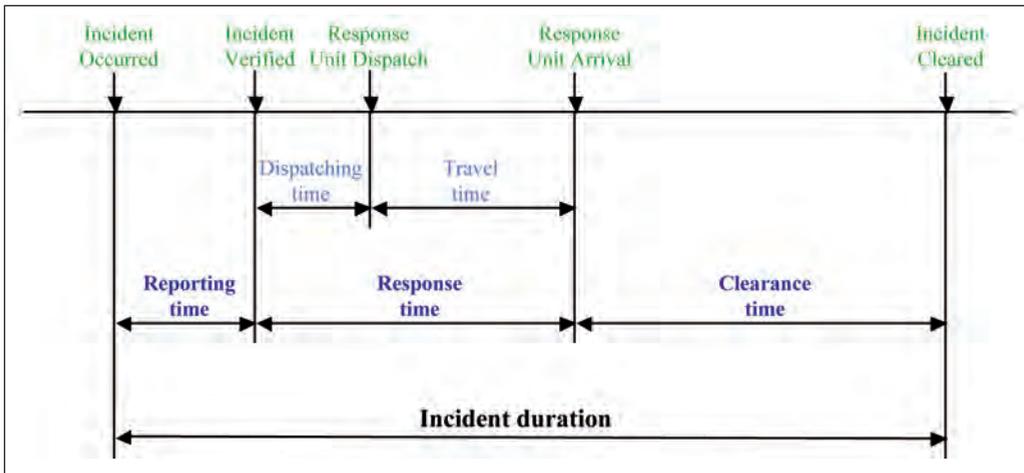


Figure 5.5: Components of incident duration

Over the past two decades a number of studies have been undertaken to investigate the feasibility of estimating incident duration. Various approaches, ranging from statistical modelling methods, to machine learning methods like neural networks, have been applied. However, a direct comparison of the results of these studies is quite difficult since datasets, used to build and validate the various models, exhibit different characteristics reflecting local variations in data collection and reporting practices.

The purpose of developing incident duration models is to determine relationships between incident duration and influencing variables. Previous studies reported similar sets of variables affecting incident duration. These variables are the incident type and severity, the number and type of vehicles involved, the geometric characteristics, the time of day and the emergency equipment (ambulances, tow truck, etc.) dispatched. Golob, et al. (1987) analyzed over 9,000 truck-involved accidents that occurred during a two-year period on freeways in the greater Los Angeles area. Statistical models were developed that relate incident duration to collision type, accident severity and lane closures. The durations of incidents were found to be log-normally distributed for homogeneous groups of truck accidents, categorized according to type of collision and, in some instances, severity. Also, Giuliano (1989) aggregated incidents into broad categories and estimated models as a function of incident characteristics for each category. Jones et al. (1991) introduced the important concept of conditional probability; that is, given that the incident has lasted X minutes, it will end in the Y th minute. The authors analyzed 2,156 incidents in the metropolitan Seattle area and found that the duration of incidents is approximated by a log-logistic instead of log-normal distribution. Ozbay and Kachroo (1999) focused on incidents having major impact on traffic and proposed the use of decision trees with the first split at the root node on the incident type variable.

In this study a normal distribution of duration for homogeneous subsets of incidents (in terms of incident type and severity) was found. Nam and Mannering (2000) applied hazard-based duration models to statistically evaluate the time it takes detect/report, respond to, and clear incidents.

The model estimation results showed that a wide variety of factors significantly affect incident times, and that different distributional assumptions for the hazard function are appropriate for the different incident times being considered. Smith and Smith (2001) proposed and applied nonparametric regression and classification trees as models to predicting incident clearance time. Lin et al. (2004) presented a system that integrates the discrete choice model with a rule-based supplemental module for estimating the duration of a detected incident.

The primary function of the embedded discrete model is to estimate those incidents having durations less than 60 minutes. For severe incidents that may last more than one hour, the system uses a rule-based supplemental module. Wang et al. (2005) developed two models, one based on fuzzy logic (FL) and the other on artificial neural networks (ANN), to predict the vehicle breakdown duration. The study demonstrated that FL and ANN can provide reasonable estimates for the breakdown duration with few variables. However, both models had difficulties in predicting the outliers. Ozbay and Noyan (2006) used Bayesian Networks (BNs) as a knowledge discovery process to accurately predict incident duration. The research showed that BNs offer an effective way to represent the stochastic nature of incident.

On the basis of these previous studies, it can be concluded that indeed no single method is expected to be the best method under all circumstances. Instead, each method seems to have its own strengths and weakness. If the full incident duration prediction horizon is to be covered, a combination of methods seems to be the best option. This view motivates the focus of this study on comparing different incident duration prediction methods.

5.3.2 Data description

The data used in this study are from the Incident Database of “Autostrade per l’Italia Spa”, for two motorway sections, respectively of two and three lanes. They refer to three months of 2005 (January, April and August) and 237 incident events.

These data are normally used for monitoring incident management operations and are related to every event disrupting the regular traffic flow on the infrastructure by obstructing part of the road. All the records of the database contain at least: 1) the beginning and the ending time and date of the incident, 2) the type of the incident (crash, disabled vehicle, vehicle fire, material on the lane), 3) the location and the detection source.

The recorded information on the incidents can be divided in three different groups:

- incident attributes (number of personal injuries/fatalities, number/type of vehicle involved, weather conditions, occurrence of events connected to the incident like cargo spill)
- operational details (presence of different response agencies, number of agencies vehicle responded...)
- variables describing the state of the infrastructure and of the traffic (number/type of lane closed, queues...)

From the statistical analysis the incident durations distribution is heavily skewed, as shown in Figure 5.6 the mean value and the standard deviation are respectively of 45 minutes and 29 minutes. About the 32% of the incidents have a duration of 30 minutes or less, whereas 78% of the incidents has a duration of less than one hour. Only 8% of the incidents are longer than 90 minutes.

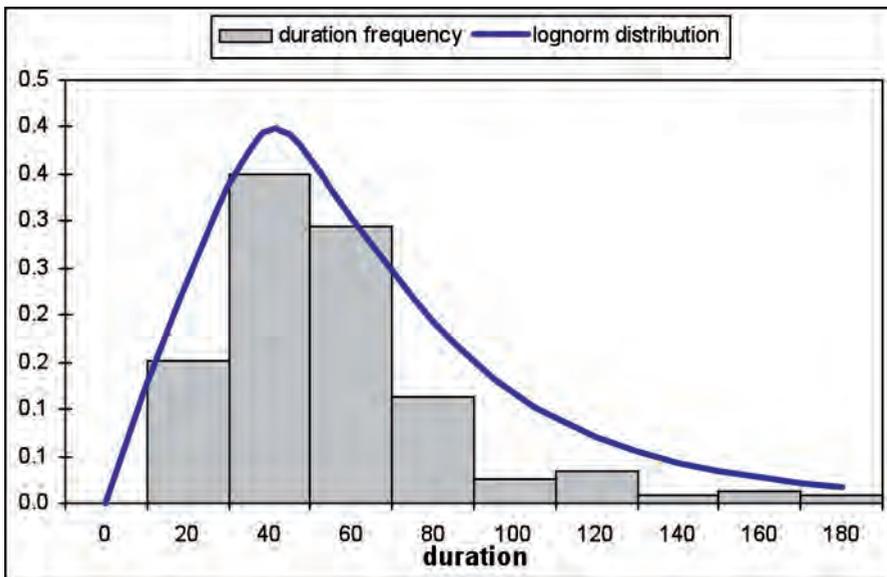


Figure 5.6: Incident duration distribution

The Chi-Square statistical test confirmed that the incident duration distribution is a log normal distribution (p -value=0.053), as found by Giuliano (1989). Analysis of variance (ANOVA) was applied to indicate which parameter information is statistically relevant for estimating incident duration. Moreover the non-parametric Kruskal-Wallis test was performed when the two assumptions of normality or homogeneity of variances, requested by the ANOVA, are not met. Statistically significant differences were found only for 13 independent variables, listed in Table 5.1. All of the independent variables are categorical with 2 possible values. Some variables that were significant for

many models in literature, like weather conditions, were not found in this study. The explanation of these apparently divergent results lies, we believe, in the limited number of incident events with non-zero values for the related variables.

Variable		Value
Incident type	Injuries/fatalities	1=Yes; 0=No
	Property damage (involving damage to the vehicle)	1=Yes; 0=No
	Disabled vehicle	1=Yes; 0=No
	Vehicle fire	1=Yes; 0=No
Incident details	Heavy vehicles involved	1=Yes; 0=No
	Pick hour	1=Yes; 0=No
	Infrastructure damage	1=Yes; 0=No
Operational details	Response service requested	1=Yes; 0=No
	Emergency Medical Services on the scene	1=Yes; 0=No
	Special agencies (heavy tow truck, HAZMAT clearance agency)	1=Yes; 0=No
Infrastructure and traffic variables	Number of lanes	1=3 lanes; 0=2 lanes
	Shoulder lane occupied	1=Yes; 0=No
	Slow lane occupied	1=Yes; 0=No

Table 5.1: Possible significant independent variables resulting from ANOVA

5.3.3 Models to predict incident duration

There are a wide range of methods that may be applicable to incident duration prediction. In this study, five incident duration prediction models are discussed and compared, namely:

- 1 Multiple linear regression (MLN);
- 2 Prediction/Decision tree (DT);
- 3 Artificial Neural Network (ANN);
- 4 Support/Relevance Vector Machine (RVM);
- 5 K-Nearest-Neighbour (kNN).

For assessing the predictive ability of these models, the incident data set was split into training and testing partitions with statistical properties similar to those represented in the original dataset. Specifically, 187 incident cases were included in the training partition for the model construction process, whereas 50 incident cases were used to evaluate the accuracy of the proposed models. Moreover, four incident duration classes were used to estimate and compare the models performance at the different duration horizons according to the incident severity: short (<30 minutes), medium (31-60 minutes), medium-long (61-90 minutes) and long (>90 minutes). For investigating the accuracy of the proposed models the Mean Absolute Error (MAE) and the Mean Absolute Percentage Error (MAPE) were adopted.

Multiple Linear Regression

Multiple linear regression attempts to model the relationship between two or more independent or explanatory variables (X_1, X_2, \dots, X_p) and a dependent variable (Y) by fitting a linear equation to observed data. In our study linear regression with the \log_{10} of the incident duration as the dependent variable was used. Next the step-wise approach was adopted for determining the independent variables that should be included within the models. The resulting best-fitting model consisted of 6 independent variables plus a constant term:

$$\log_{10}(\text{duration}) = 1.66 + 0.22 X_1 + 0.15 X_2 + 0.16 X_3 + 0.20 X_4 - 0.09 X_5 - 0.28 X_6;$$

where:

X_1 = Emergency Medical Services on the scene;

X_2 = Heavy vehicles involved;

X_3 = Pick hour;

X_4 = Infrastructure damage;

X_5 = Number of lanes;

X_6 = Vehicle fire incident.

All coefficients are statistically significant at the 95% level, however, the explanatory power of the model is rather poor as indicated by $R^2 = 0.32$. The addition of other variables does not significantly improve the accuracy of the predictions. The MAE value is 17 minutes.

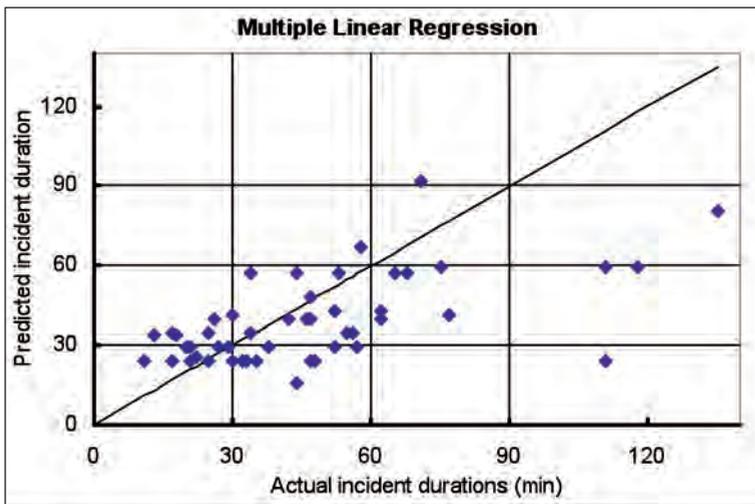


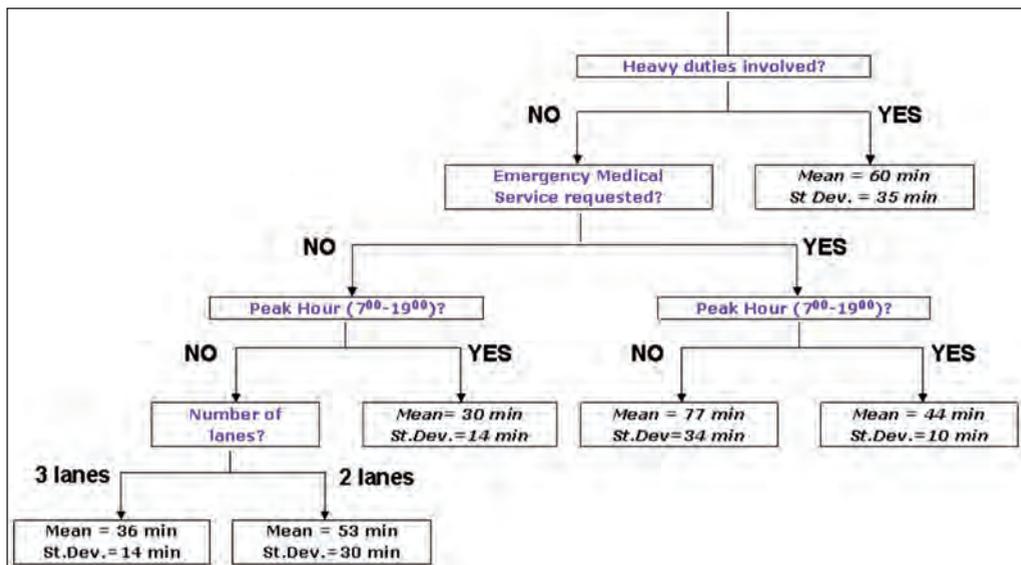
Figure 5.7: Regression results versus duration test data

Figure 5.7 shows the results of applying the MLR model to the test data set. From this figure, it can be seen that the model tends to underestimate the actual values for the incident cases with higher durations partly because the data set used has a relatively 233

small number of severe incidents; the 5 incident cases with the longest durations have an absolute error higher than 30 minutes. Moreover 33 out of 50 incident cases have an absolute error less than 20, while 45 out of 50 incident cases have an absolute error less than 30 minutes. The MLR model is more accurate in predicting short duration incident cases where the MAE value is 9 minutes. The MAE value achieved by the MLR model is comparable to that obtained by Ozbay and Kachroo (1999) with DT models, and better than that of Smith and Smith (2001) using KNN models.

Prediction/Decision tree

A Prediction/Decision tree can perform classification for predicting what group a case belongs to, as well as regression for predicting a specific value. DTs are non-parametric-based models as they make no assumption on data distribution and, as a result, they may be applied in situations where less is known about the application in question. As with all regression techniques we assume the existence of a single output (response) variable and one or more input (predictor) variables. It is called a decision tree because the resulting model is presented in the form of a tree structure or a set of logical if-then conditions (tree nodes). The visual presentation makes the decision tree model very easy to understand and assimilate. A decision tree is built through an iterative process of splitting the data into partitions, and then splitting it up further on each of the branches. The process continues until each node reaches a user-specified minimum node size and becomes a terminal node. The terminal nodes of the tree contain the predicted output variable values.



234 Figure 5.8: Decision tree for incident duration prediction

In our study, the statistical CHAID (chi-squared automatic interaction detection) procedure was used to iteratively segment the incident data set into mutually exclusive sub-groups according to the explanatory power a set of predictors has with regard to the incident duration. The application of CHAID procedure to the incident data set allowed us to identify the four variables (Heavy vehicles involved, Emergency Medical Services on the scene, time of day, and number of lanes) that are most influential in incident duration. The results of the CHAID procedure are illustrated by the tree diagram reported in Figure 5.8.

Validation test results showed that the developed DT model has satisfactory precision in predicting the duration of most incident cases. In particular 37 incident cases out of 50 are predicted with less than 20 minutes of prediction error. However, some outliers with a large difference between recorded and predicted incident duration exist, especially in long duration incident cases. Better prediction performance is given by the DT model for incident cases with medium-long durations, where the MAPE and MAE values are respectively equal to 18% and 12 minutes.

Artificial Neural Network

An Artificial Neural Network (ANN) model is a flexible mathematical structure capable of describing complex nonlinear relations between input and output datasets. ANNs have been successfully applied to prediction and pattern classification problems. The architecture of ANN models is loosely based on the biological nervous system. Although there are numerous types of ANNs, the most commonly used type of ANN is the Multi-Layer Perceptron (MLP). This is a feed forward, fully-connected hierarchical network typically comprising of three types of neuron layers: an input layer, one or more hidden layers and an output layer each including one or several neurons. The behaviour of a neural network is determined by the transfer functions of its neurons, by the learning rule and by the architecture itself. In our study, the number of neurons in the input layer is determined by the 13 most significant variables affecting incident duration, while a single neuron in the output layer is made up of the incident duration value being predicted. Moreover various ANN architectures, with one or two hidden layers and different number of neurons in the hidden layers, were trained using the Levenberg-Marquardt back-propagation algorithm. The best performing ANN architecture resulted from using a single hidden layer of 15 neurons and from employing tangent-sigmoid transfer function.

The MAE value for this ANN model is slightly more than 17 minutes; 32 out of the 50 incident cases have been predicted with an absolute error less than 20 minutes. In Figure 5.9 the ANN model results are reported versus the actual durations. The ANN model has a satisfactory accuracy for the incident cases with duration longer than 60 minutes. However the ANN model tends to slightly overestimate the prediction values for the short duration incident cases, where the MAE value is equal to 18 minutes.

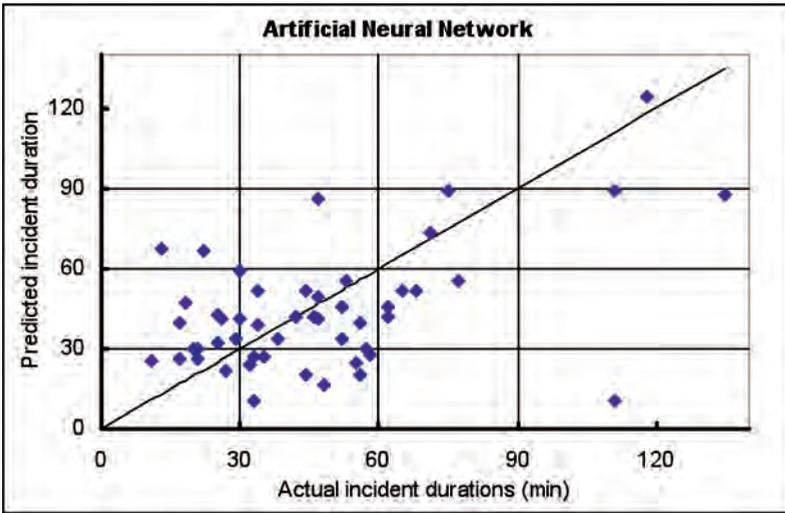


Figure 5.9: Neural Network prediction results versus duration test data

Support/Relevance Vector Machine (SVM)

The Support Vector Machines (SVM) are supervised learning machines born in the 1990s in the framework of statistical learning theory, based on the Structural Risk Minimization Theory (SRM) developed by Vapnik and Chervonenkis (Vapnik, 1999), to clarify the properties of generalization of the learning machines. The SVM are a powerful methodology to solve problems of classification, regression, pattern recognition, density estimation (Cristianini and Shawe-Taylor, 2000), with the supervisor's output as a function of a linear combination of kernel functions centred on a sub-set of the training data, consisting of the so called support vectors.

In recent years many different SVM implementation models have been developed, based on a variety of error functions, or kernels or optimization techniques. Tipping (2001) elaborated a new support vector machine, called Relevance Vector Machine (RVM), merging the Vapnik theory with the Bayesian statistics. The RVM obtained accurate predictions with fewer support vectors than classic SVM, bypassing some SVM constrains.

In this study, different SVM and RVM were trained in the MatLab environment, using the Gunn (1997) and the Tipping software packages, varying kernel and error functions with different sets of independent variables. Using the Cauchy Functions Kernel and the training dataset composed of the 13 significant explanatory variables from ANOVA, the best performing RVM was obtained with 45 support vectors. This model gave the smallest MAE, equal to 15 minutes. The validation test results, reported in Figure 5.10, demonstrate that the RVM model provides good performance in predicting durations for incident cases belonging to the medium and medium-long duration groups.

The MAEs for these two groups are respectively of 12 and 10 minutes. In particular for the medium-long duration incident cases, the MAPE is rather small (15%). Only for the four longest duration incidents are the prediction absolute errors greater than 30 minutes, while 38 out of the 50 incident cases have an absolute error less than 20 minutes.

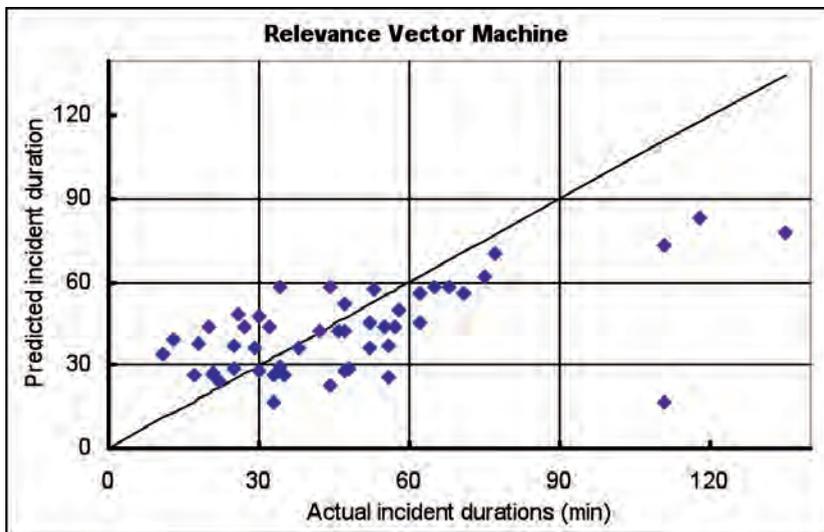


Figure 5.10: RVM prediction results versus duration test data

K-Nearest Neighbour (KNN)

The non-parametric K-Nearest Neighbour (KNN) method offers an alternative to the traditional parametric regression model. Through this method, the estimate/prediction for a current observation is simply based on weighting the contributions of the k nearest neighbours, so that the nearer neighbours contribute more to the average than the more distant ones. The neighbourhood is defined using independent variables which are known in both the past and current observations. In order to define the relative closeness of a given point, the form of the similarity (or distance) measure must be specified. Similarity measures based on absolute differences or Euclidean distance functions are typically applied. In building the KNN model the choice of k can strongly influence the quality of predictions: a small value of k leads to a large variance in predictions; alternatively, setting k to a large value may lead to a large model bias.

In our study the optimal value for k was 10 and an appropriate distance metric, based on the number of matching independent variables between past and current incidents, was applied since all the independent variables are binary (0/1) in form (Smith and 237

Smith, 2001). Furthermore weight factors for each independent variable, given by the absolute difference between the average duration of the two related yes/no samples, were used to compute the KNN distance.

The KNN model results for the 50 accidents in the testing set are illustrated in Figure 5.11. This model averages over 17 minutes of error between the predicted and actual incident durations. Slightly more than half of the predicted durations are within 15 minutes of the actual time. The KNN model also tends to overestimate the prediction values for incidents of relatively short duration the majority of the time, while underestimating them for incident cases of relatively long duration. This indicates that there may be some outliers with large duration that are influencing the predicted time.

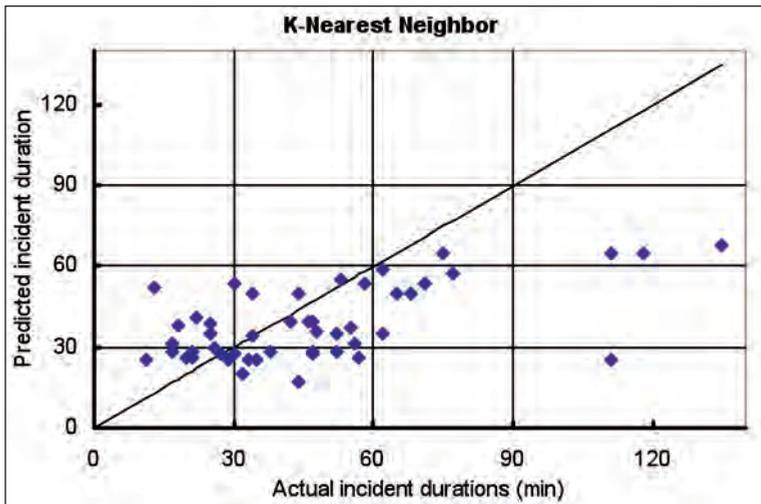


Figure 5.11: KNN prediction results versus duration test data

5.3.4 Comparisons and conclusions

On the whole, the models proposed in this study achieve good performance in terms of prediction accuracy for incidents with duration less than 90 minutes, matching what was obtained in similar studies reported in the literature. Summarizing the findings of this study (see Figure 5.12, next page), we can state that the lower MAE is obtained by the RVM model.

The MLR is the best performing model for short duration incidents, as obtained by Ozbay and Kachroo (1999) using DT models. In the incident cases with medium/medium-long duration, the best predictions are achieved by the RVM model. Also the DT and KNN models give predictions for these duration groups with low absolute errors, however the DT and KNN results are worse than those expected, most likely due

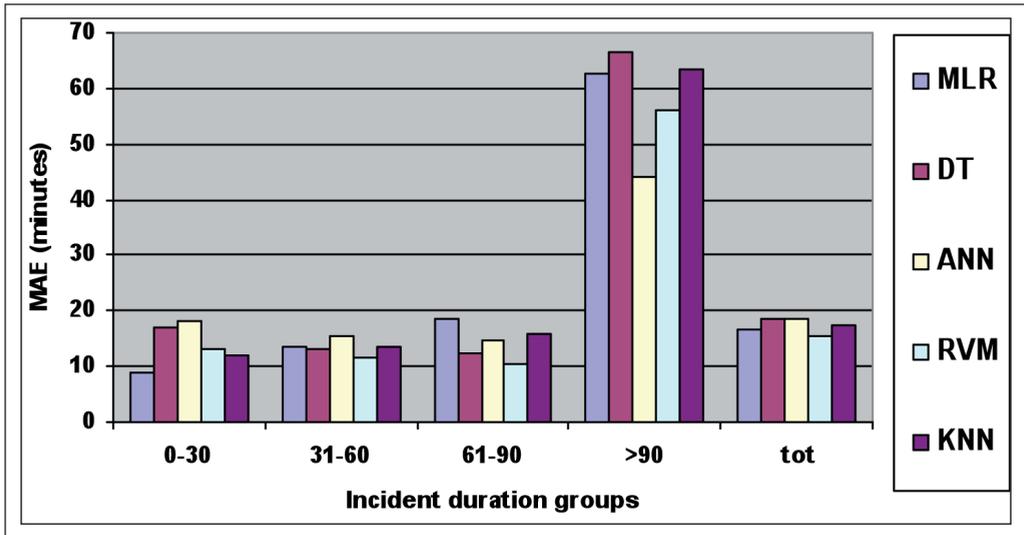


Figure 5.12: MAE values achieved by the proposed model

to the limited number of particular incident cases in the training dataset. The ANN is the only model that can predict an incident longer than 90 minutes. Moreover the ANN model gives the best results for long duration incident cases, with the lowest MAPE, even if greater than 30%. All proposed models tend to have a relatively low accuracy for incidents with long duration partly because the dataset has a relatively small number of severe incidents. Therefore a more extensive collection of severe incident cases, with duration time longer than 90 minutes, is needed to improve model performance. In particular, when excluding the most atypical outlier (with long duration but characterised by zero values for almost all the significant variables), the MAE of all the proposed models decreases by 10%.

To conclude, this study shows very promising practical applicability of the proposed models in the incident management process and in the traveller information diffusion context. However the results of this study show that the proposed models need to be further improved and upgraded with a larger number of incident cases given the small size of the dataset used. Moreover, it is likely the proposed models could have a limited accuracy when used in other geographical contexts where different incident management and emergency response actions take place. In order to ensure that the proposed models are able to deal with different conditions, a wider-scale data collection effort is needed to be undertaken. Finally, to achieve higher prediction accuracy and robustness an important direction for future study is to further investigate the potential advantage of combining the predictions obtained using some or all of the proposed models into a single prediction on the basis of their prediction skill at the different incident situations.

Acknowledgment

The authors would like to thank Autostrade per l'Italia Spa for kindly supplying the incident data used in this study.

5.4 A decision support system (DSS) for traffic incident management in roadway tunnel infrastructure

S. Mitrovich, G. Valenti, M. Mancini

5.4.1 Introduction

The Italian roadway and motorway network is characterized by a high density of traffic and tunnels. In recent years the risks of incidents have increased as many road infrastructures, including tunnels, were designed several decades ago to carry lower traffic volumes than the current traffic levels and were built with technical requirements that with time have become outdated. Currently all main Italian roadway and motorway companies are involved in the process to improve the tunnel safety levels according to the recent EU directive that defines minimum harmonised organisational, structural, technical and operational safety requirements for all tunnels longer than 500 meters in the Trans-European Road Network.

The SITI project, lead by the *TRAIN* Consortium (an Italian association for industrial research in the field of transport) and co-financed by the MIUR (Italian Research Ministry), aims to study, develop and demonstrate a set of innovative technologies to improve the traffic monitoring processes and the safety levels inside tunnels. The project introduced a new approach to the matter: the “*Dynamic Tunnel*” vision considering tunnels as a whole with the road network before and after, like a complex system in continuous evolution. Among the main objectives, the SITI project included the realization of a DSS to help traffic control centre (TCC) operators and supervisors select and best implement traffic management measures in response to the occurrence of an incident, with the aim to minimize negative consequences of incidents on traffic, such as formation of congestion and queues, travel delays and risks for secondary incidents. Incidents in tunnels, though they are not so frequent, have more serious consequences than those in the open, in terms of human lives and infrastructure repair costs, but also for their negative effects on traffic congestion.

The present section describes the current development of the TRIM (Traffic and incident management) system: a DSS designed to assist traffic control centre (TCC) teams to effectively and safely manage traffic flows and mitigate traffic congestion in the event of an incident, in particular an incident inside a tunnel or along the surrounding roadway. The TRIM system has been conceived and designed by an ENEA (Italian National Agency for New Technologies, Energy and the Environment) working group for the *TRAIN*

Consortium, within the SITI project. TRIM includes both macro- and micro-scale traffic simulators and is able to prevent crisis situations and make traffic control operations more effective during emergency events, both locally and area-wide.

TRIM is also designed to support an off-line task of traffic supervisors, like the study and formulation of proper traffic diversion emergency plans, and some on-line tasks of TCC operators, like the early estimate of impact area and incident duration and the selection of the most suitable traffic response plan, based on a set of parameters such as the incident severity level, the estimated duration and the current/predicted traffic demand approaching the incident site and across the overall road network. The post-incident traffic management strategies supported by TRIM include the activation of proper traffic control measures at the incident site and on the roadway infrastructures affected by the traffic incident and the dissemination of information to drivers. For this purpose TRIM is interfaced with all the existing local traffic control devices (traffic lights and VMS) and with travel information systems including WEB and mobile phone. Although TRIM is born within the SITI project framework, the system in perspective will not be “tunnel dependent”; it can also work inside a motorway TCC or an urban area TCC, where it can be linked with the existing equipment providing real-time data collected from traffic sensors. By reducing the duration of the incident and maximizing the use of the available roadway capacity during incidents, both the economic cost of congestion and the associated aggravation can be reduced. The result is more reliable travel, shorter trips and an ability to accommodate more trips within the existing roadway infrastructure.

5.4.2. Basic elements of incident and traffic management

The occurrence of incidents, besides its direct impacts in terms of property damage, injuries and fatalities, can quickly lead to congestion and associated travel delay, wasted fuel, increased pollutant emissions and higher risk of secondary incidents. Traffic management in the post-incident scenario is a primary tool in minimizing the impact and reducing the probability of secondary incidents and is a crucial step to minimize the negative consequences on network efficiency and safety. The basic elements of an emergency response plan are the traffic channelling and control schemes to regulate traffic flow past the incident site, the traffic diversion on appropriate routes to relieve traffic demand at the incident site and the dynamic dissemination of information to drivers regarding traffic conditions, changes in roadway geometry, operating traffic speeds and routing.

Incident phases and duration

An incident represents any unpredictable occurrence that disrupts traffic flow for a period that lasts longer than the incident itself and, temporarily, reduces roadway capacity. An incident can range from disabled vehicles or debris dropped along the side of the road-

way up to major collisions involving fatalities, fires or hazardous material spills. Severe incidents involving significant damage to roadway and structures, such as multi-vehicle collisions, tanker truck explosion and fire in tunnels, can cause severe disruptions in the flow of traffic including disturbances to the economy of a whole region. However minor incidents, such as disabled vehicles, are responsible for the majority of the total delay caused by incidents.

The amount of delay and impacts that results from the incident depends on the duration of the following five distinct phases, often overlapping:

1. *Detection* that determines the occurrence of the incident;
2. *Verification* that defines the precise location and nature of the incident;
3. *Response* that concerns the activation and dispatching of personnel and equipment to the incident site;
4. *Clearance* that includes the removal of vehicles, debris and spilled material from the roadway to restore the complete roadway capacity; and
5. *Recovery* that consists of dissipating the queue at the site of the incident once the roadway is cleared in order to restore as quickly as possible the normal traffic conditions.

Together the first four phases represent the total duration of the incident or the period of time ranging from the occurrence of the incident to the complete restoring of the roadway capacity. The recovery phase largely depends on the extent of the disruption to traffic flow caused by the incident and on the effectiveness of the traffic management measures implemented soon after the occurrence of the incident.

Measures at the incident site

Traffic management includes the implementation of a range of traffic control measures at the incident site and on the roadway infrastructure affected by the incident aimed at minimizing traffic disruption, reducing the probability of secondary collisions and protecting response teams working on the incident. The control at the incident site is required to facilitate the orderly and safe movement of traffic past the incident by channelling traffic with flares, cones, delineators and warning signs into the lanes that remain open to traffic.

Typical techniques implemented for the on site control are:

- roadway shoulder utilization to provide additional capacity around the incident scene;
 - ramp diversion from the exit ramp immediately preceding the incident site, to divert traffic temporarily off the roadway onto a nearby parallel street and back onto the affected roadway downstream of the incident scene
- 242 - contra-flow lane diversion (for major incidents causing the full closure of the car-

riageway for several hours) to allow upstream trapped traffic to utilize a travel lane from the opposing roadway direction;

- alternate one-way movement when two-way traffic is reduced to one-way traffic and traffic in both directions must use a single lane. Alternate one-way traffic control may be effected by means of temporary traffic signal or by flagmen.

Limiting traffic demand

Traffic management may also require the implementation of measures that temporarily limit traffic demand approaching the incident location to prevent congestion or vehicles queuing upstream of the incident. In this context typical traffic control strategies are traffic diversion on alternative routes and ramp metering. By effectively controlling entering vehicle volumes with traffic signals at the entrance ramps located upstream from the incident site, the ramp metering strategy can help keep the traffic density below the critical level and provide a smooth flow of traffic on the section of roadway immediately upstream of the incident.

The diversion of the traffic flow approaching the incident area on appropriate *alternative routes* is the only way to alleviate congestion especially in the occurrence of major incidents requiring the long-term closure of multiple lanes or full closure of the roadway. However, the effectiveness of traffic routing depends on the availability of alternate routes and their level of congestion. A *diversion strategy* involves the determination of where and how much traffic should be diverted and the sequence of roads forming the diversion routes that are best suited to handle this increased traffic demand. A diversion strategy may also involve the modification of signal timing and the activation of guide signs along the diversion routes to allow the effective and safe passage of diverted traffic.

Information to drivers

A major element of traffic management in a post-incident scenario is the dissemination of information to drivers approaching the incident area regarding traffic condition, changes in roadway geometry, operating traffic speeds and routing by deploying various output devices (variable message signs, lane control signals, radio broadcasts, etc.). Drivers' response to the provided incident-related information is crucial for successfully diverting traffic, reducing secondary incidents and improving response teams safety at the incident scene

5.4.3 TRIM Functions

In this context a DSS with the capability of storing, analyzing, and displaying geographically referenced information and data on network characteristics, traffic and incidents, predicting incident duration and traffic delay, generating and implementing appropriate traffic response plans to different incident scenarios and controlling their effectiveness in

reducing traffic disruption and related impacts, appears to be the perfect tool to greatly increase the efficiency of incident and traffic management.

TRIM was conceived to carry out the following specific functions:

- to integrate and display information flowing from the surveillance and control devices, installed inside the tunnel and on the surrounding road network, to the TCC (i.e.: traffic flow sensors, traffic signs, VMSs, meteo sensors, AVL, etc.);
- to perform traffic simulation studies at macro/micro scale to evaluate feasible traffic response plans under different traffic conditions and incident scenarios;
- to store, query and analyse network characteristic data, incident scenarios and historical traffic data, needed to define possible diversion routes and control strategies and to feed traffic simulation and prediction models;
- to select on the basis of predefined rules the most appropriate traffic plan in response to an incident and suggest to the TCC operators the steps needed for its implementation; and
- to provide during the incident management period reliable estimates of the network traffic conditions to verify the effectiveness of the proposed traffic response plan.

Based on these requirements the TRIM design aims to make available a new software tool suitable to help the TCC operators in their tasks, especially when they face dramatic traffic congestion caused by major incidents inside or in the proximity of a tunnel, involving long duration clearance operations and affecting high traffic volumes.

In particular TRIM is designed to help the TCC operators to effectively perform:

- off-line tasks, concerning the study and design of a set of traffic response plans to face possible incident scenarios through the use of micro/macro traffic simulation and prediction tools;
- on-line tasks during the incident management process, concerning the selection, implementation and follow-up of the most appropriate traffic response plan, in relation to the incident severity level and the traffic demand approaching the incident site.

The main off-line and on-line functions of the TRIM system are outlined in the flowchart illustrated in Figure 5.13. The flowchart shows the different steps followed from the occurrence of the incident to the implementation and control of the traffic response plan.

On-line tasks

After an incident has been detected and verified through information coming from the different available sources (traffic sensors, CCTVs, police patrols, etc.), the incident characteristics (i.e.: type, location, time of occurrence, vehicle involved, injuries involved, fatalities involved, etc.) are fed by the TCC operators into TRIM through a convenient graphical user interface (GUI).

Once TRIM has received input information describing the incident, the first step is to estimate the incident duration on the basis of the operational experience accumulated from previous incident management operations. Duration forecast, which refers to the expected time interval ranging from the incident occurrence to the end of clearance operations, is made by TCC operators directly or using a suitable prediction model incorporated in TRIM. Starting from the predicted incident duration and taking into consideration the reduction in roadway capacity and the current/predicted traffic demand, TRIM estimates the extent of the impact area and the travel delays that will be caused by the incident.

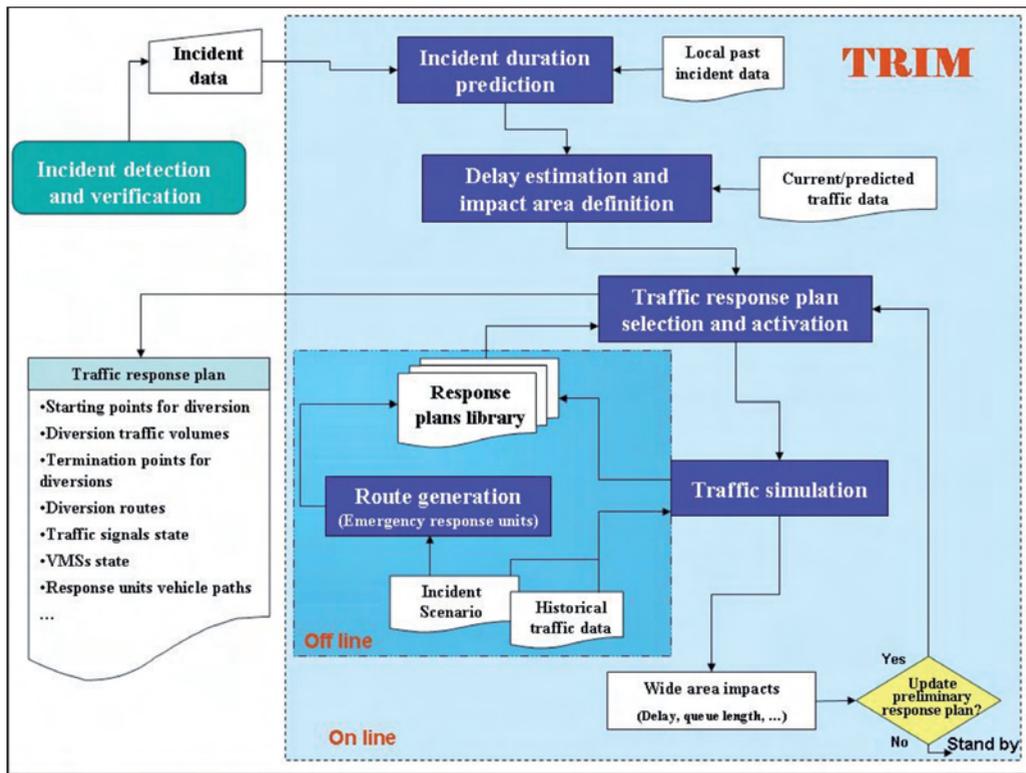


Figure 5.13: Flowchart of TRIM basic functions

All these estimates are then used to select a preliminary traffic response plan specifying the set of strategies chosen to manage traffic flow (such as diversion points, % of diverted traffic demand, termination points, diversion routes, new timing for traffic signals, emergency signals, messages to be displayed on the VMSs, etc.).

The plan selection is performed by TCC operators, with the help of a specific TRIM software module, on the basis of a set of rules pre-defined by the traffic experts.

According to the selected traffic response plan, TRIM proposes to the TCC operators, step by step, the predefined traffic management measures to be implemented. The traffic response plan is integrated with information about the best paths to be taken by the involved emergency response vehicles to reach the incident site more quickly and vice versa.

Traffic micro-simulation is then performed, starting from the preliminary estimates about the incident duration, the current traffic data received from sensors, the selected alternative routes and the other traffic control measures taken by the TCC operators, according to the selected response plan. Traffic micro-simulation reproduces in a virtual environment the spatial and temporal evolution of the traffic flow on the roadway network affected by the incident with the final aim to offer an immediate, reliable estimate of the effectiveness of the preliminary traffic response plan. If the micro-simulation results (such as delays and queue lengths) differ significantly from the expected traffic performance, TRIM helps the TCC operator to select and implement a new and more effective traffic response plan. On-line traffic micro-simulation can be performed again when updated information on the actual traffic demand or about the actual duration of clearance operations become available in order to verify the effectiveness of the traffic response plan under implementation.

Off-line tasks

The TRIM off-line functions aim to study and evaluate feasible traffic plans in response to possible incident scenarios through the use of micro and macro scale traffic simulation models. Micro-simulation that captures the behaviour of vehicles and drivers in great detail is performed to evaluate traffic congestion evolution at local scale, in the proximity to the incident site, due to the complicated structure of the models involved. On the other hand macro-simulation, due to their more aggregate nature, is performed to evaluate the traffic conditions at a wider scale (i.e. regional/national network), to choose the best diversion points for the specific incident and to determine the best alternative routes for the chosen diversion points. Finally, an additional off-line function of TRIM is the generation of shortest paths, so that emergency responders can avoid blocked or slow routes and quickly reach the incident site.

5.4.4. General Architecture and software modules

General architecture

TRIM is designed to work inside a traffic control centre (TCC), able to perform traffic surveillance, traffic control and driver information functions, of a motorway, an urban area or a long tunnel. The general architecture of the TRIM system is illustrated in Figure 5.14.

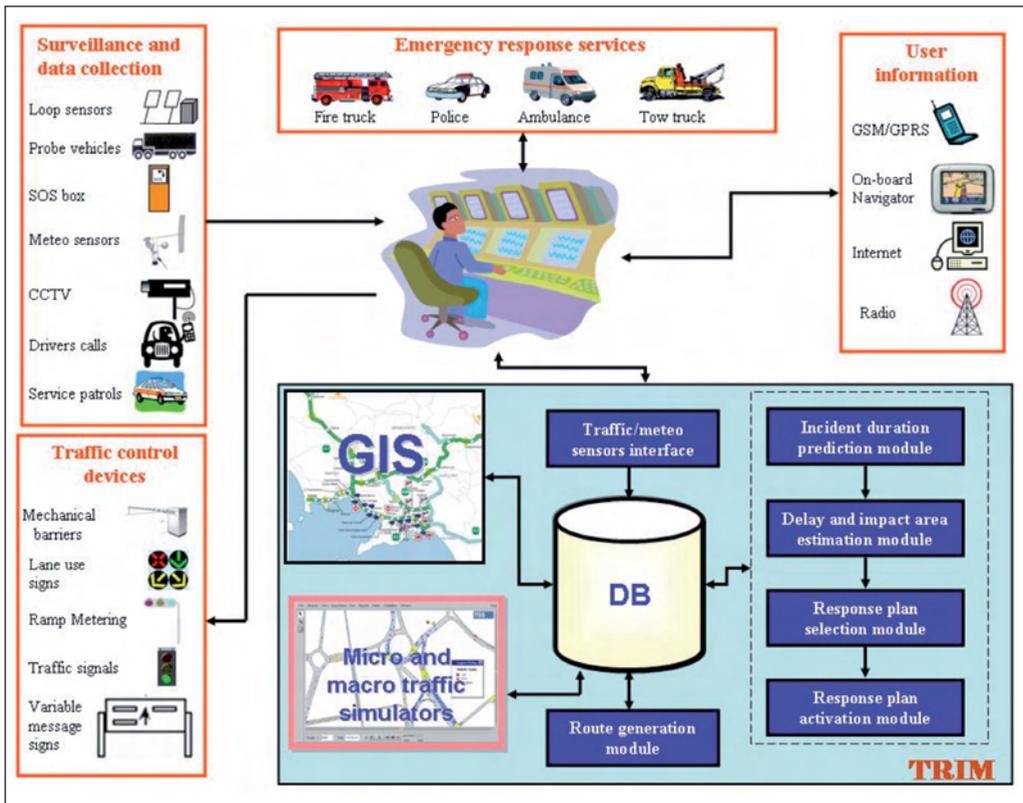


Figure 5.14: TRIM general architecture

The architecture of the TRIM software is derived from the *Mobility* system, a DSS for urban traffic planning, and from *Merlino*, a DSS for on-line traffic management, designed and implemented by ENEA. TRIM architecture includes a traffic simulator at macro-scale (MIAURB from D'APPOLONIA), which is directly embedded in the system software architecture, and a micro-simulator (AIMSUN) that will be linked with the system as well. Traffic simulators will enable TCC operators to perform detailed real-time analysis of the network traffic conditions under the current control strategies during the incident management period.

Figure 5.15 (next page) shows the connections between the main software elements of the system: the Data Base (DB), the GIS (Geographic Information System), the Graphic User Interface (GUI), used by operators and supervisors, and the traffic simulators at macro-scale and micro-scale (SIM) linked with the system.

The software architecture and the modules composing the TRIM system are shown in Figure 5.16.

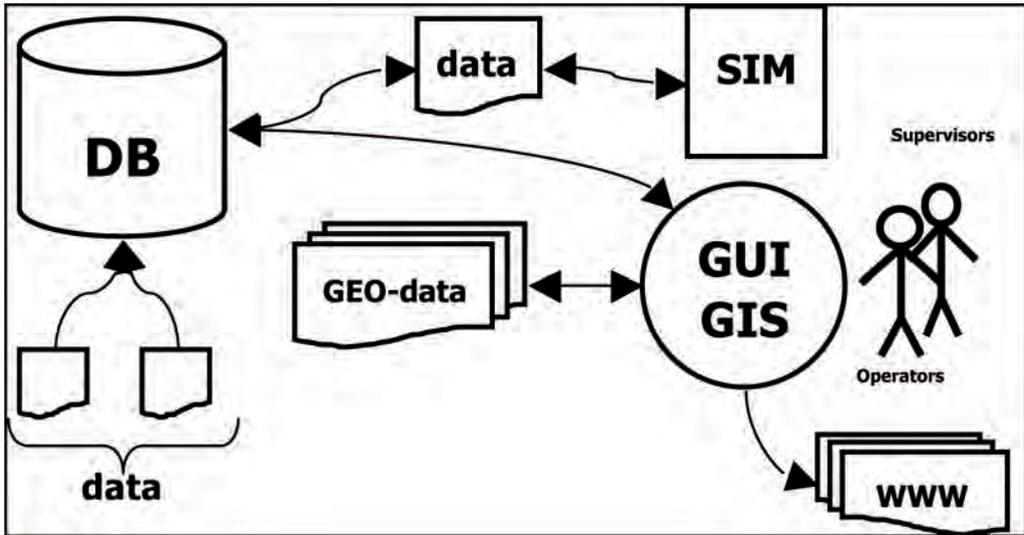


Figure 5.15: Scheme of the main software elements

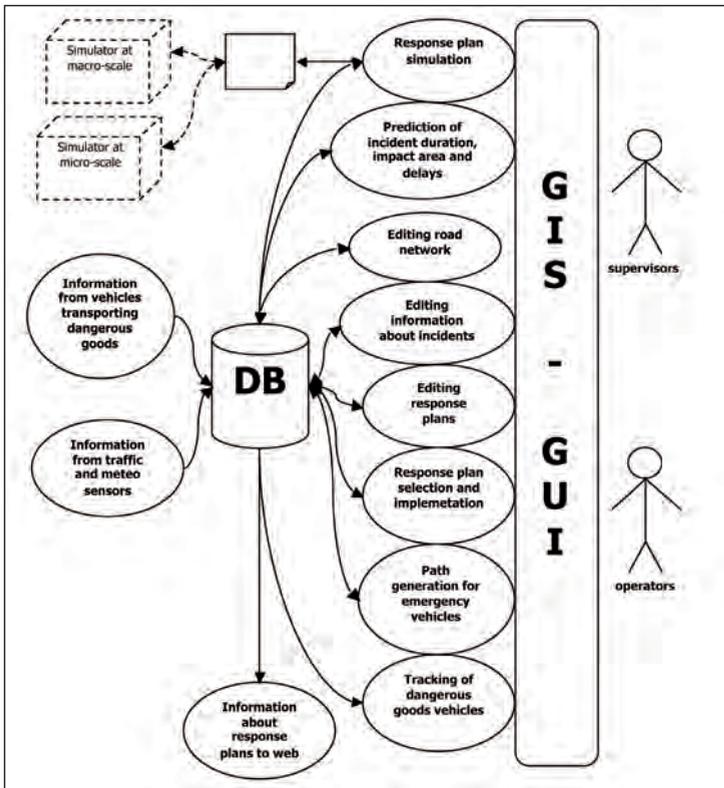


Figure 5.16: TRIM software modules

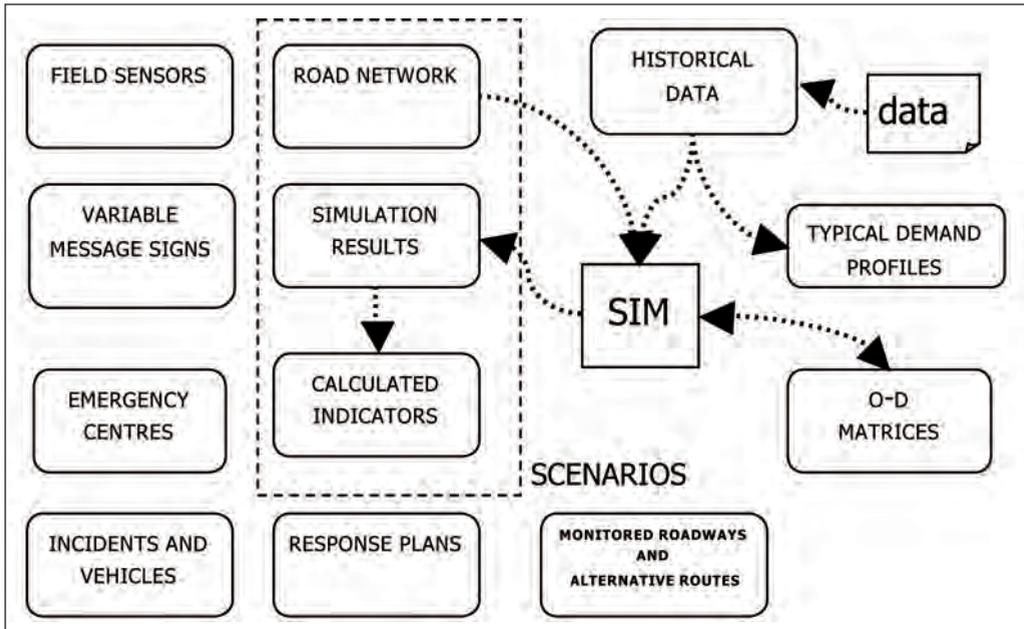


Figure 5.17: Macro-entities stored in TRIM alphanumeric DB

Software modules

TRIM is composed of:

- a *relational database* (MySQL) designed to store, query and update historical incident data, traffic data, traffic network characteristics, data exchanged between the various system modules, simulation results and traffic response plans. The main information families (macro-entities) stored in the alphanumeric Data Base are indicated in Figure 5.17, namely:
- a *GIS-based user interface* (ArcView) that enables the TCC operator to display the roadway network, the real-time traffic data and the status of the control devices on a background map, to run on-line and off-line prediction and simulation procedures, to analyse and display the results in multiple views and tables, to define and implement traffic response measures;

and of the following software modules (shown in Figure 5.16):

- an interface module to gather *on-line traffic and meteo data* collected by sensors installed inside the tunnel or on the surrounding roadway network;
- an interface module to acquire data from sensors and GPS devices installed on-board of the *vehicles transporting dangerous goods*;
- a module dedicated to simulate different traffic management strategies (response plans) and emergency scenarios, which is connected with the traffic simulation tools

at macro-scale (MIAURB from D'APPOLONIA) and at micro-scale (AIMSUN), in order to model and evaluate the associated evolution of the traffic flows;

- three user interface modules for editing respectively road network and network characteristics, information about incidents and the response plans;
- a module, including three procedures, to estimate the *duration of the incident*, the *extent of the incident impact area* and the *delays* suffered by drivers in case of non-intervention;
- a module to *select the most appropriate traffic response plan*, on the basis of a predefined set of rules, and to help step-by-step the TCC operator through the tasks needed to *implement the plan*, including the provision of incident-related information to drivers and the application of traffic control measures on the road network affected by the incident; a path generation module to enable the shortest, fastest *routing of emergency response vehicles* from the various key locations, including hospitals, fire and police stations, to the incident scene;
- a module for *tracking* the vehicles transporting *dangerous goods*, on the basis of data received from sensors and GPS devices; and
- an interface module to make available on the WEB the information about emergency situations and the traffic response plan under implementation.

TRIM prediction tools

The above mentioned software module dedicated to estimate the *duration of the incident*, the *extent of the impact area* and the *delays* suffered by drivers in case of non-intervention, incorporates three procedures:

- a first procedure, to estimate the incident duration, implementing a statistical model and using variables related to operational and incident-type factors, that can be realistically obtained in real-time under incident conditions, and statistical parameters tailored and calibrated on the basis of the time experienced in past incidents occurred in the local area;
- a second and a third procedures, implementing two different algorithms based respectively on the *deterministic queuing* and on the *shock-wave* models, to calculate the queue length upstream of the incident (for a period of 24 hours after the incident), the maximum queue length, the queue discharging time, the total cumulative delay and the average delay per vehicle.

In the above mentioned first procedure the incident duration can be also estimated by means of an alternative method, using a decision tree where the first decision is based on the incident type.

The maximum queue length, the queue discharging time and the delays are forecast by the second and third procedures, starting from the incident duration estimated by the first procedure, the estimated (by the TCC operators) reduction in the roadway maximum

capacity and a careful prediction of traffic demand for the 24 hours after the incident. The prediction of traffic demand is produced on-line by the adopted algorithm by means of a weighted linear combination between the long term predicted values, based on traffic historical data, and the actual measured values received from traffic field sensors. The long-term prediction of traffic demand, based on traffic historical data, is elaborated off-line and can be memorized as “*typical profiles*”, which are vector values reporting traffic flows and speeds for each time interval of 20 minutes (72 values a day).

The *typical profiles* are then corrected on-line with the actual values coming from field sensors. The weighting parameters in the linear combination are calibrated using, when available, local historical traffic data. The different values produced by the prediction tools are then used for the selection of the most suitable traffic measures from a library of past/simulated response plans, together with the traffic flows and speeds measured by the field sensors located on the roadway concerned and on the possible alternatives.

Traffic response plan selection

The response plan selection procedure is automatically started when the estimated delay and maximum queue length are beyond predefined threshold values and is based on the following parameters:

- incident severity (classified according to typical situations),
- predicted incident duration,
- current/predicted traffic demand approaching the incident site,
- the current/predicted traffic demand on the alternative routes.

The set of rules used in this software module is formulated by traffic experts, who possess specific knowledge and expertise to solve traffic congestion problems and, in the rule-formalising process, the connected traffic simulation tools provide data to the traffic experts for deriving consistent rules for the selection of the best traffic plan in response to an incident.

For each of the possible incident scenarios a number of response plans are evaluated off-line, with the help of the above mentioned macro/micro traffic simulators, and classified on the basis of the resulting performance (mainly in terms of total travel time and total delays of vehicles), and are then stored by the traffic experts in the TRIM system. When the procedure is started on-line, the nearest neighbour algorithm of the software module, on the basis of the current incident and demand characteristics (the above mentioned parameters), selects the scenario most similar to the actual case from the already studied “base case” and then retrieves from the stored response plans the one having the best performance. The suggested response plan must be approved by the TCC operator before his implementation. The actual cases and the relevant actual performance of the implemented response plans are also stored into the “base case” of the software module, and in this way the “experience” embedded in the module is continuously improving.

In addition the module can be also customized and the TCC operators have the opportunity to select the optimization parameters and the performance indicators, which are used in the procedure.

5.4.5 Conclusions

Roadway and tunnel agencies are now more frequently asked to develop and improve incident management to expedite response and clearance processes and to minimize the traffic flow disruption and the potential for secondary incidents. Traffic management is a key step of the complex incident management process as it can greatly reduce the amount and duration of the resulting congestion. Traffic management embraces the selection of the most appropriate traffic control strategies, such as signal modification and traffic diversion, and the dissemination of incident-related information to drivers to avoid the incident and adjust driving behaviour.

This section has presented a DSS (TRIM) designed to assist traffic control centre personnel in determining the appropriate strategies, aimed to effectively and safely manage traffic in post-incident scenarios, and in the execution of steps required for their implementation and control. TRIM has the capability to use both historical and real-time sensor data, to collect and categorize incident information, to simulate all candidate traffic response plans prior to their implementation, to perform the immediate preliminary estimate of incident impacts in terms of duration, delay and geographic extent, to select and implement the most appropriate response plan and, finally, to model and control real-time traffic conditions during incidents. The proposed DSS is under testing in the inter-urban highly congested corridor extending from the southern neighbourhoods of Naples to the town of Sorrento. The corridor is defined by the “SS 145” roadway (named Sorrentina) suffering from relatively high incident rates and including a 1400 meters long tunnel.

The evaluation of Infomobility services

6.1 Introduction

The importance of evaluation of transport systems is well established. Ambrosino et al (2004), for example, have described a detailed methodology for the systematic evaluation of telematics-based flexible transport services. This normally involves the preparation of a detailed evaluation framework which comprises a number of distinct steps including the identification of assessment objectives and priorities for key user groups and the development of evaluation indicators for the assessment categories specified (e.g. economic viability, service provision, technical performance etc.).

This chapter provides two case studies of good practice in evaluation each illustrated by an example of an infomobility application which has been discussed in earlier chapters. The first (Section 6.2) introduces a methodology, known as DESTINO, for identifying the main factors which need to be considered in the decision process when designing and delivering a flexible transport service. Such preliminary work at the design stage of a transport system is extremely important as it forms an integral part in the development of an evaluation framework. The DESTINO methodology is designed to be transferable and is thus available for the planning and evaluation of a variety of infomobility applications. The second case study (Section 6.3) is a detailed method for the analysis of performance reliability of transport services which draws on work conducted as part of a COST research action on Buses with a High Level of Service (Action TU 603). In addition to a state-of-the-art review of the indicators and methods currently used for evaluating public transport services performance a proposal for evaluating reliability of a service is illustrated by a synthesis of experience on some European BHLS lines.

6.2 A decision support framework for flexibly delivered public transport services

J.F. Brake, J.D. Nelson, S.D. Wright

In recent years, many statutory authorities and public transport operators have been experimenting with or considering flexibly delivered public transport systems – mainly with a view to improving social inclusion in rural and urban areas that are difficult to cover by conventional public transport (see for example Sections 3.11 and 4.4).

There are many varied and often *inter-related decisions* to be taken if successful flexible transport service operation such as Demand Responsive Transport (DRT) is to be achieved - this includes the consideration of strategic policy, option appraisal, funding and legislative constraints, consultation with end users, operators and other partners and decisions on technologies applied, vehicle specifications and tendering processes. This is clearly a very complex task and one for which there are currently no established and recognised procedures to guide the planner through the decision process.

In the UK context (and elsewhere) a current fear of users, whether in rural or urban areas, is that many new services which have been introduced as a result of Central Government Bus Challenge or ‘Kickstart’ funding will be removed, due to poor forward planning, heavy expenditure on unsuitable technology and low patronage figures, as soon as the funding ends.

This view is confirmed by the recent review of DRT in Scotland conducted by Halden *et al* (2006) who state: “...*there has been very little advanced analysis of the potential user base, destinations and trip purposes of the DRT projects. As a result there have been no targets from which to assess whether services have met their design aims. Routes to designing services have typically been more dependent upon: ‘intuition’ and area knowledge of service commissioners; resource levels (i.e. available funding levels); and noise (calls from local bus fora / community councils) than they have been on detailed analysis of potential users through in depth plans to enhance accessibility for users. There needs to be a much clearer assessment of the reasons why services are being introduced to ensure value for money is to be obtained from future DRT provision*”.

The Halden report concludes that the long term sustainability of most of the pilot DRT projects set up by the (then) Scottish Executive is uncertain and to improve long-term sustainability of services they suggest: “*There is a need to foster joint working in the delivery of DRT services to enhance the sustainability of services between a wide range of stakeholders involved in DRT including: Public Sector (Transport); Public Sector (Non-Transport related); Voluntary / Community Transport Groups; Commercial organisations; employers and other private organisation*”. Similar conclusions on the need for partnership working have been advanced in recently completed work for the UK Department for Transport (DfT) (Brake *et al*, 2006).

The DEcision Support framework for flexIbly delivered public traNspOrt services (DESTINO) project has developed a *web-based decision support tool* that helps meet these stated requirements and overcome the identified and continuing problems by:

- encouraging integration and adherence with DfT requirements for accessibility planning practice to identify if, and where, the introduction of a DRT service is most appropriate;
- informing the planner on suitable service design and system components for specific applications;
- increasing the opportunity for sustainable operation by promoting, from the outset, the possibilities for partnership funding and joint working in the service delivery; and
- providing information on estimated costs balanced against predicted revenues thereby reducing the risk of poor financial decisions being made, resulting in unsustainable services being introduced and then withdrawn at a point when a community may have become dependent on the service.

6.2.1 DESTINO: DEcision Support framework for flexIbly delivered public traNspOrt services

The DESTINO project has developed a *web-based decision support tool* to aid local authority public transport planners in the design and implementation of appropriate flexible public transport solutions, particularly registered DRT services.

Previous work undertaken by the authors on establishing good practice for DRT services (Brake *et al*, 2006; Brake and Nelson, 2007) along with initial consultation with professionals involved in DRT planning and operations outlined existing approaches to DRT service design and implementation and identified a number of the key factors influencing DRT service planning and delivery.

The initial consultation established the basis for a more extensive consultation exercise and led to the creation of a comprehensive questionnaire circulated to public transport planners from every Local Authority across the UK (180 in total).

Additionally, the questionnaire was circulated to non-Local Authority individuals and organisations known to be involved in the planning or operation of existing DRT services, ranging from voluntary sector and community transport organisations to bus operators (80 in total).

The Consultation

The questionnaire was designed to elicit the main considerations and approaches which have shaped flexible transport services up until now and to share lessons learnt for future service planning. In total, 31 responses were received and all respondents were sent a copy of the DESTINO report summarising questionnaire returns.

The main finding from this consultation was that there was a lack of consistency in the approach used by Local Authorities when planning DRT services. When looking at the reasons for choosing DRT, the policy document most often cited as being responsible for the introduction of the DRT services was the Local Transport Plan (LTP). However, there appears to be a lack of adherence to strategic policy objectives as laid down in these plans as 60% of respondents who had been through the process of planning registered DRT services more than once said there had been a change in the objectives they applied when they subsequently introduced new services. Furthermore, 76% of respondents did not consider accessibility planning at all when designing the DRT service. As it has been a requirement, since March 2006, for all local authorities to include an accessibility strategy in their Local Transport Plans it was considered appropriate to make it a prerequisite of using the DESTINO tool that accessibility assessments be conducted according to the Government's *accessibility planning guidance*. This is used to identify the need for and the suggested location of flexible transport services based on national and regional policy objectives and priorities, thereby ensuring a consistent and integrated policy approach to subsequent use of the DESTINO tool.

The DESTINO Tool Design Framework

The consultation with known DRT practitioners established the factors (and elements within factors) which need to be considered in the decision process when designing and delivering a flexible transport service. This led to the development of a structured framework for the tool consisting of 17 factors; 10 related to planning, 6 related to delivery and a cost model factor (illustrated by Figure 6.1).

Factors visited early on in the tool relate to planning decisions and generally describe the environment into which the service is to be introduced, identify strategic policy goals and user needs and establish constraints (related to geography, legislation, and organisational structures of local stakeholders) in meeting these goals and needs. Existing service provision, opportunity for joint working and promoting shared use of resource is also considered. This leads to a set of requirements for specifying the service design and to a narrowing of the options for selecting vehicle designs and choosing appropriate operators. The final 7 factors relate to the implementation of the service and allow the user to choose suitable service providers, vehicles and technology components for effective delivery of the planned flexible transport service.

Associated with each choice at the implementation stage are estimates of both capital and operating costs which feed into the final cost model along with estimates of revenues generated through fares. If the chosen solution does not meet budget constraints then the user can review and alter choices at the implementation stages, but being careful that these are still sensible. If a solution still cannot be found within budget then the planning stage can be re-visited to relax certain constraints, thereby altering the service

design and minimum vehicle/operator requirements allowing the implementation stage to be re-run with new data.

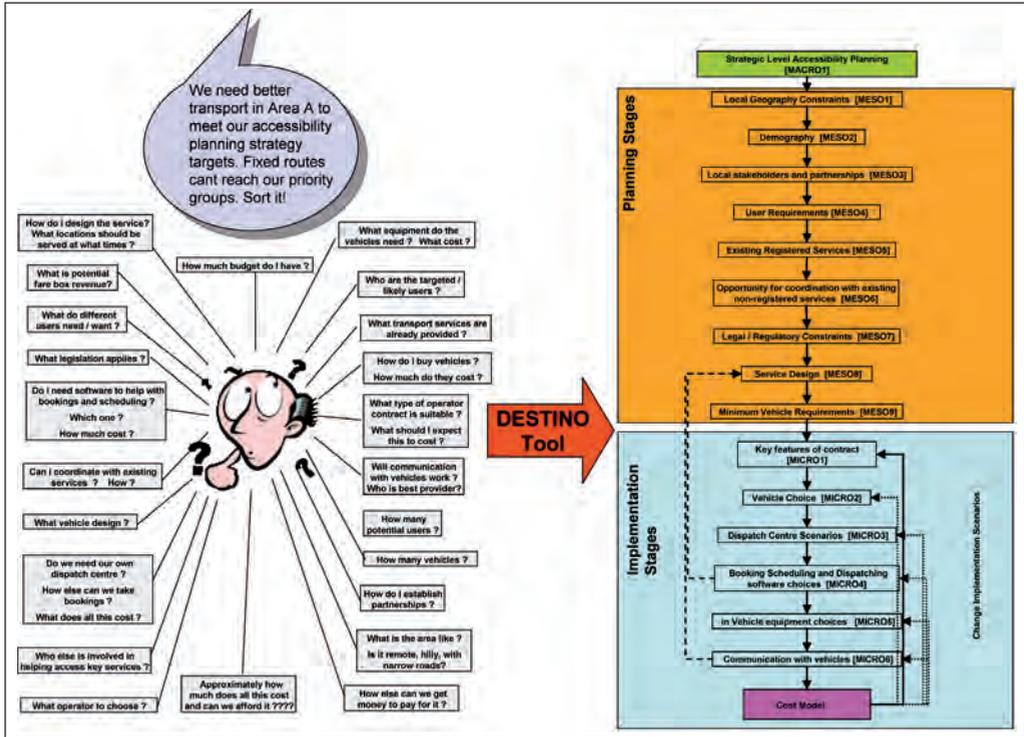


Figure 6.1: The DESTINO Tool Design Framework

Delivery of the DESTINO Tool

The DESTINO tool has brought together a library of detailed information and good practice guidance on considerations for each factor (Wright et al, 2007). The descriptive content for each factor has been built up over time through consultation with practitioners (questionnaire survey responses and workshops/meetings), team knowledge gained from other project experience and desk-based research and review. The tool provides a description of each factor based on a standard format template and additionally provides links to relevant published good practice guidance, case study examples and other relevant information which exists in the public domain.

For each factor users are provided with a *description* of what the factor is, *why* it is *important* and *how* it *influences* or is influenced by other factors. As well as links to *published material* and *best practice* relating to the factor, other resources are available to review or download such as *case study* information, *templates* for surveys and useful *websites*.

This information appears to the user as a standard web-site and allows the tool to be used as a UK focussed on-line *information resource* for flexible transport services (Figures 6.2 and 6.3). It provides an easy to use interface to additional information which will be helpful for finding answers to queries and learning of best practice for implementing planning decisions by anyone involved in the procurement and delivery of specific aspects of DRT services.

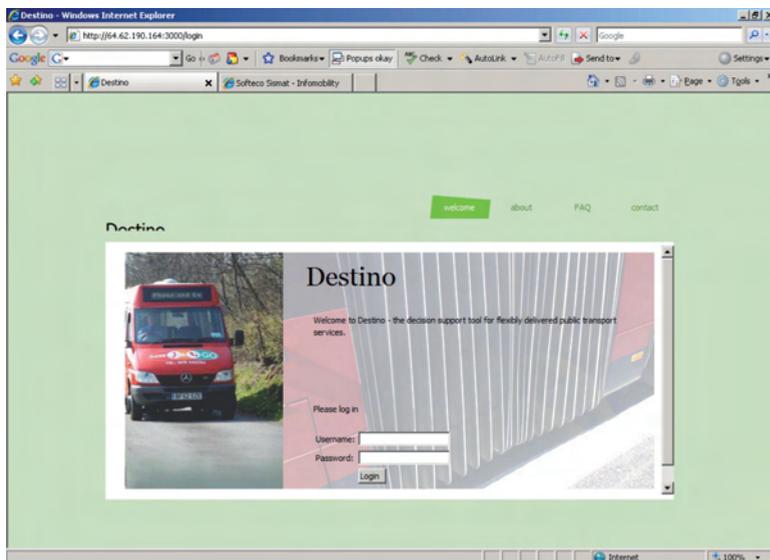


Figure 6.2:
DESTINO home page

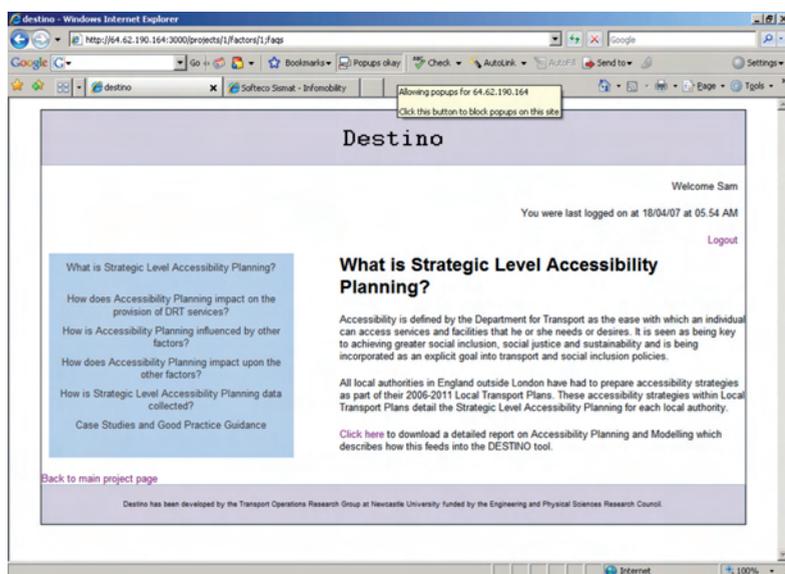


Figure 6.3:
Factor Information
front page for
Strategic Level
Accessibility Planning

The second mode of use for the DESTINO tool is as an aid in the public transport *planning process* by those with strategic area wide responsibilities – local authority transport planners. For these users the tool provides a more rigid structure that requires the user to enter key data at the various stages in the planning process. Having reviewed the information and followed the guidance for data collection the user will be prompted to input to the tool their choices and relevant data. The data capture is designed to ensure the information is collected according to the critical path sequence defined by the framework illustrated in Figure 6.1. This prompts the user to undertake tasks in the correct order so that, where appropriate, data entered at any one task is available to inform decisions made in later tasks. The tool stores the data and may draw on it for presentation back to the user to aid decisions later on - or it may be stored until required for presenting final reports. Data entry from the user is captured through web forms or graphically via Google Earth mapping with additional DESTINO help sheets provided to explain how this can be done.

Development of the DESTINO Tool

A key consideration in the development of the tool was the desire for it to be able to grow and potentially change over time as a result of its use and feedback from practitioners. Therefore a fundamental aspect of the design was the need for the tool to be as flexible as possible in terms of its structure and content. Another desire was that the users are able to take ownership of the tool and feed its growth. This required the tool to allow users to upload information themselves and to be able to edit content they felt was outdated or perhaps misleading. For the prototype version of the tool a moderator has been assigned to ensure suitable changes are introduced in a controlled way, but ultimately it is hoped that the tool can become maintained by the users themselves.

These requirements led to a unique and novel approach to development of the tool. State-of-the-art techniques in database backed web development using Ruby on Rails were utilised to meet these requirements. Ruby on Rails technology provides an open source web framework which uses incremental and iterative development to create strong yet flexible web applications that users require.

A domain specific language has been developed (based on Ruby on Rails technology). This domain specific language allows abstraction of the factor object content from the logic which creates the tool architecture. This is what enables simple editing of existing as well as addition of new objects (factors and factor-elements within the tool). The strength of this for the DESTINO application is that the tool is very flexible and organic, allowing it to grow and evolve through its life responding to feedback from users. Standard web development technologies which have a static structure do not have the agility to provide for this level of flexibility. Added advantages are that objects, which users are making changes to, need only be defined once and so duplication and the risk of error

are reduced. The logic permeates the changes throughout the rest of the application. The logic itself is written in a client friendly way allowing tool administrators to proof read and verify the logic code without specialist programming skills. Again this facilitates maintenance of the site to accommodate organic growth.

Deployment of the DESTINO Tool

The DESTINO tool is being provided free, as a web-based application, to all local authorities interested in flexible transport services. Prospective users need to register, but thereafter have access to all features of the tool. Users can be individuals or can be established as part of a larger workgroup all involved in various aspects of the same project (a project consisting of the design and delivery of a single flexible service). Users can create and work on several projects simultaneously. The DESTINO User Guide (Wright et al, 2007) has been developed to aid the validation process.

Although the information provided by the tool on each factor is comprehensive, the intention is for the users to build on the information provided by adding their own experiences and links to resources they have found useful. In other words the DESTINO tool provides the structure or skeleton onto which the users add “meat to the bones”.

Two levels are provided within the tool for this. They can add information relevant only to their own project to share only with their workgroup, or they can add information which they feel is generic and can be useful to the wider DRT community to be published and visible to all tool users. This way the tool becomes self-maintaining and current. This is particularly important when dealing with legislation which may change over time – although relatively slowly – and technologies which are changing more quickly. Costs, of course, are changing all the time and the tool avoids specifying costs and instead recommends the users consult with the suppliers or operators to obtain costs relevant to their circumstances. Costs are therefore input to the tool by the users rather than provided to the users by the tool (although guidance on which costs are appropriate is provided).

DESTINO is not a piece of software which removes the need for user involvement in the planning and delivery of flexible services. It actually requires significant user input through data collection and data entry. What the tool is intended for is to provide guidance, focus and direction to the data collection process and provide aids to decision making in the form of summary reports of previously collected data, data visualisation through digital maps and feasibility/legitimacy checks with data already captured where appropriate.

6.2.2 Summary

260 There continues to be uncertainty surrounding the future development and sustainability of flexible and DRT services but significant interest is maintained by many local authori-

ties. This section has introduced a methodology for identifying the main factors which need to be considered in the decision process when designing and delivering a flexible transport service. The DESTINO methodology is designed to be transferable and is thus available for the planning and evaluation of a variety of infomobility applications.

6.3 Transit reliability performance analysis. An application to BHLS

D. Gattuso, M. Galante, A. Lugarà, S. Napoli

As part of a research action on Buses with a High Level of Service (Action TU 603) particular attention has been directed to the analysis of performance reliability of transport services. After a brief presentation of the EC COST research programme and a brief definition of BHLS (Buses with a High Level of Service), this section is divided into three parts:

- a state-of-the-art of the currently used indicators and methods for evaluating public transport services performance and in particular the indicators of reliability;
- a proposal for evaluating the reliability of a service; and
- a synthesis of experience on some European BHLS lines.

6.3.1 COST Action on BHLS

In order to improve sustainable mobility in urban areas, different European cities have experimented with new bus lines (e.g. the so-called “Quality Bus Corridors” in England and in Ireland, “Bus à Haut Niveau de Service” in France, “Linea ad Alta Mobilità” in Italy, “Trunk Line” in Sweden, etc. In this context, the COST research programme has launched a specific Action called “**Buses with a High Level of Service**” (BHLS) involving 14 EU countries and lasting four years from October 2007 to October 2011. This COST Action aims to better understand the reason for this trend as well as to encourage a useful way to enhance the image of the bus¹.

BHLS (CERTU, 2005) is a public road transportation concept for the structuring of services of the network that meet a set of efficiency and performance criteria, coherently integrating stations, vehicles, circulation lanes, line identification, and operating plans. “Bus”, in this case, means a mode of road transportation to be considered in its broadest sense:

- a vehicle that does not have to permanently follow a path determined by a physical rail or rails and that uses the roadway;
- a standard, articulated or semi-articulated bus (class I, according to Geneva regulation n°36 of 1958);

1 See: www.bhls.eu.

- a thermal, electric (trolleybus type for example), or hybrid motorization; or
- a bus or coach (Class II and III).

BHLS seeks to come close to the comfort of rail transportation with bus type infrastructure. Its layout design (right of way, lanes, crossings, stations) does not exclude the possibility of future construction of a tram on the same site.

6.3.2 Performance indicators for public transport

The evaluation of the performance of a public transport system is a complex problem due to the different objectives pursued by different stakeholders (service provider, customers, community). The main interest of the service provider, namely the operator of the public transport system, is the provision of a service which meets and satisfies the demand, complying, at the same time, with the resource constraint. The service users would like the service to be as cheap as possible, but also to be reliable, safe and of a good quality. Each stakeholder has different needs and therefore a different perception about the performance of the public transport system.

Usually, transport evaluations aim to check the differences between current and past performance. The evaluation can be used to provide a benchmark with another company. Obviously, the comparison needs to be based on shared and uniquely determined parameters. According to the available literature on the subject, the methods to analyze the performance of public transport companies are classified in two different types:

- parametric methods, such as Stochastic Frontiers and Econometric Models of Production; and
- non-parametric methods, like Data Envelopment Analysis and Analysis through Indicators.

The methods based on indicators provide an analytical approach to analyze the public transport system (OCSE, 1980; Miller et al., 1984; Fielding et. al., 1985; Mac Dorman, 1988; Gattuso, 1992; CERTU, 1997; Gattuso et al., 2002).

In the conceptual model in Figure 6.4 (next page) (Fielding et. al., 1985), the definition of effectiveness and efficiency indicators is linked with the knowledge of data about:

- service inputs (workforce, capital, energy);
- service outputs, (vehicles-hour, vehicles-km, seats-km);
- utilization of the provided service (passengers, passengers-km, revenues).

A suitable ratio between output and input measures allows definition of the costs of efficiency indicators (work efficiency, vehicle efficiency, efficiency in fuel consumption, efficiency of maintenance, output per unit of cost). Effectiveness cost indicators are derived by the ratio between utilized service and input measures (utilized service per unit of cost, revenue production per unit of cost). Finally, with the ratio between utilized

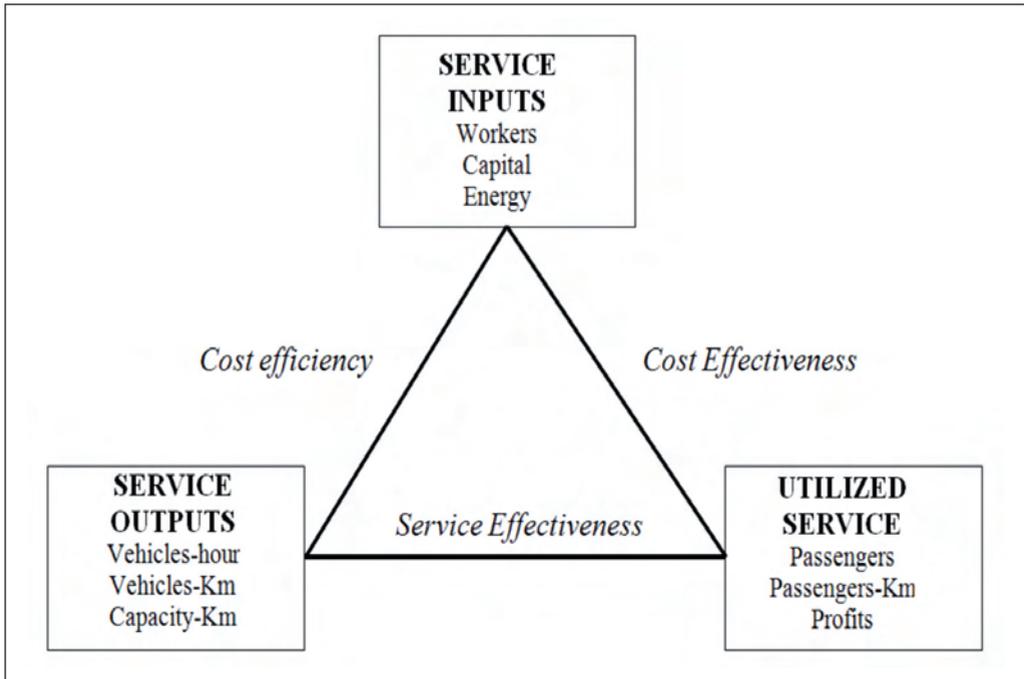


Figure 6.4: Conceptual model of Fielding et al. (1985)

service and output measures, one can obtain the service effectiveness indicators (utilized service, operating safety, revenues production, public economic support).

An evolution of the conceptual scheme is provided by Gattuso (Gattuso, 1992). In order to evaluate public transport performance, the manager has to quantify three different aspects:

- system productivity (efficiency);
- users satisfaction level (effectiveness); and
- regularity and reliability of service.

Efficiency (system productivity) describes the relations between provided output and resources used for the production. The level of satisfaction of users can be obtained through parameters which capture the effectiveness and level of utilization of the transport service. Regularity and reliability assess the differences between the provided and the scheduled service. The definition of the above parameters is linked to the relations among the different types of measures (Figure 6.5):

- company's resources;
- service provided;
- service scheduled; and
- service utilized.

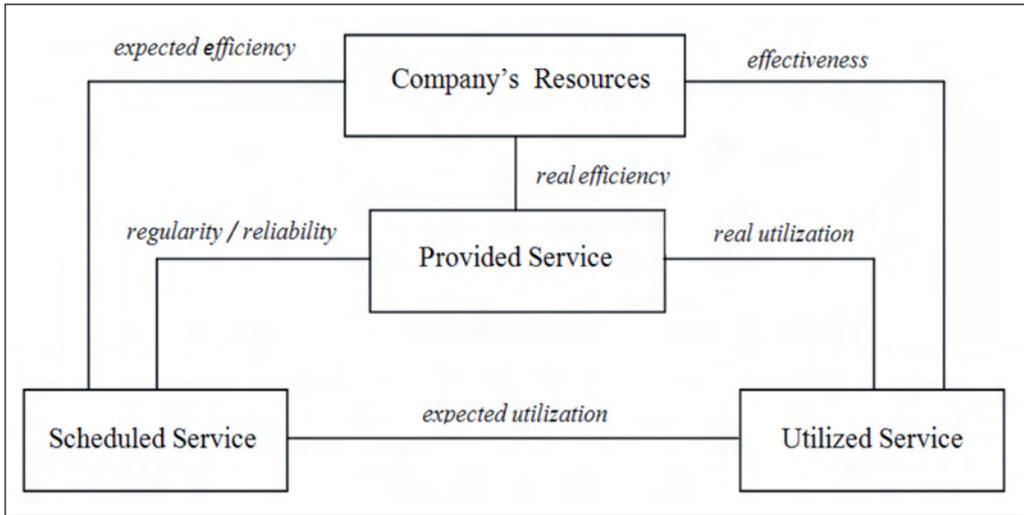


Figure 6.5: Scheme of the relations among service provider interest

6.3.3 Approach to the analysis of reliability parameters

In order to reduce congestion in cities, and the relevant negative effects (pollution, accidents, worse quality of life) it is important to promote more attractive public transport services. Transport services should be efficient and of a good quality; the service quality level can be assessed, and also improved, by taking into account the reliability parameters.

The term reliability has several definitions, particularly within transport, and different modes have different sources of reliability which depend on the uncertainty of individual aspects of the journey. The term 'reliability', in transport, can be directly connected to the uncertainty of the duration a trip from an origin to a destination point.

Due to this uncertainty, the user has to assume a certain time interval of tolerance. Accepting this, the destination can be reached on time even in the case of adverse conditions. Reliability is equally important for passengers and operators. Under unreliable conditions, the transportation system is prone to changes and variations due to the unpredictable order of events. Difficulties for the operators on scheduling services and resource planning often result in unreliable services. Furthermore, unreliable services are usually randomly loaded, causing issues of passenger overloading and breaching of loading licenses.

The concepts of reliability can be referred to as:

- departure time (punctuality and variability around expected departure time),
- travel time (variability around expected travel time); and
- arrival time (punctuality and variability around expected arrival time).

Besides the various new activities around the reliability of transport systems, an OECD working group has recently produced a report on the “Surface Transport Networks: Improving Reliability and Levels of Service” (JTRC, 2009). The OECD study defines reliability as “the ability of the transport system to provide the expected level of service quality, on which users have organized their activities”. According to this definition, reliability can be improved either by actually supplying better reliability or by changing expectations on the level of reliability.

Vincent (2008) identifies the following components of public transport reliability (Table 6.1):

- *punctuality*, defined as adherence to schedule and measured through the mean delay percentage outside of the comfort zone (e.g. 1 minute early to 5 minutes late);
- *cancellation*, defined as whether a scheduled bus actually arrives; cancellation can happen at the departure or during the trip; it can be measured by mean delay;
- *variability*, around expected time, usually measured using standard deviation; and
- *waiting time variability*.

Term	Definition	Standard measures
Punctuality - departure - arrival	Adherence to schedule	Mean delay Percentage outside of “comfort zone” (e.g. 1 min-early to 5 min late)
Cancellations * - at departure - during trip	Whether a scheduled train or bus actually arrives	Mean delay (which is a function of headway)
Variability around expected - departure time - travel time - arrival time	Spread around “expected x time” Note: “expected x time” can be: - average time; - targeted time	Standard deviation
Waiting time variability	Spread around average waiting time	Standard deviation

*The UK rail industry uses “reliability” to refer to the term described here as “cancellations”

Table 6.1: Public transport reliability (Vincent, 2008)

From the user point of view, the variability of the travel time experienced corresponds to the main index. Indicators must focus on such quantification of travel time variability. Several definitions for travel time reliability exist and many different relevant indicators have been proposed (Lomax et al., 2003; Van Lint, 2004). Some of them are statistical range indicators such as the “Standard Deviation” or the “Variation Coefficient” com-

puted for a given time during the day or for a given day of a week. Other approaches are related to the Buffer Index (BI), Planning Time Index (PTI) and Travel Time Index (TTI) as proposed by Turner (Turner, 2006). Figure 6.6 shows a scheme useful to define these parameters.

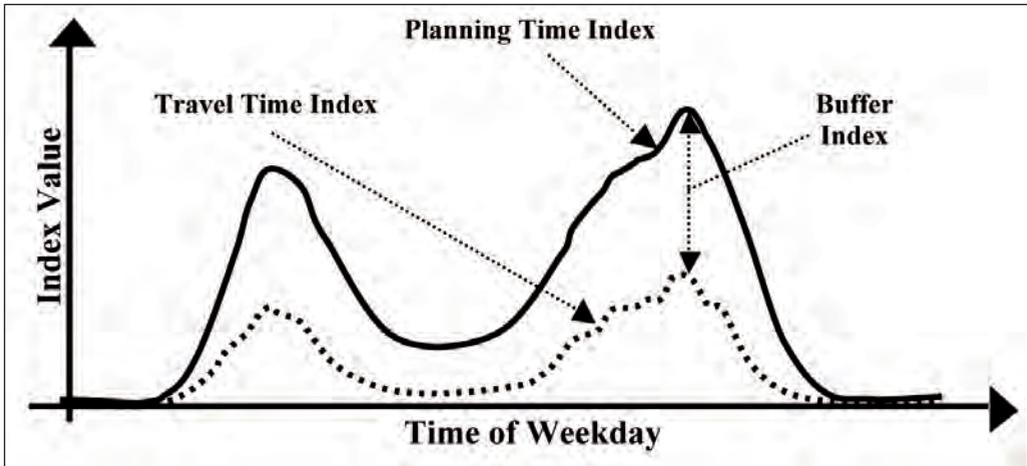


Figure 6.6: Reliability indicators relationship (Turner, 2006)

The BI appears to relate particularly well to the way in which travellers make their decisions (Bhouri and Haj-Salem, 2009); it is defined as the extra time a user has to add to the average travel time in order to be on time 95% of the cases (trips made) and it is computed as the difference between 95th percentile travel time (TT_{95}) and mean travel time (M), divided by mean travel time:

$$BI = (TT_{95} - M) / M$$

The 95th Percentile Travel Time (TT_{95}) expresses how much delay will be experienced in the heaviest travel days. The Buffer Index is a useful parameter in the user's assessment of how much extra time has to be allowed due to uncertainty in the travel conditions.

Planning Time Index is the total time needed to plan for on-time arrival 95% of the time compared to the free flow travel time. It is computed as 95th percentile travel time (TT_{95}) divided by free-flow travel time ($TT_{free-flow}$):

$$PTI = TT_{95} / TT_{free-flow}$$

As these indicators can use the 95-percentile value of the travel time distribution as a reference of the definitions, they take into account more explicitly the largest travel time delays.

The Travel Time Index measures the average time to travel during peak hours compared to free flow conditions, computed as mean travel time divided by free flow travel time.

$$TTI = M/TT_{free-flow}$$

The TTI indicator is known as a congestion indicator and will be used to compare reliability with the congestion state.

6.3.4 Proposed approach to evaluate reliability

The calculation of reliability indicators can be based on the detection of:

- vehicle passage times at the stops;
- run frequency;
- number of runs meeting the scheduled time at the stops and at the terminals;
- number of deleted runs; and
- delay time accumulated.

Reliability measures relate to the service provider and do not include the perceptions of users (e.g. variability on waiting times).

The following are some of the main reliability indicators that can be obtained:

- Punctuality indicator, as % runs on time at terminals:

$$PT = R_O / R_{Tot}$$

where:

R_O = number of runs on time ($|\Delta_i| \leq 1$ minutes) at terminal;

R_{Tot} = total number of runs;

- Punctuality indicator, as % runs on time during the trip:

$$PS = R_{OS} / R_{Tot}$$

where:

R_{OS} = number of runs on time ($|\Delta_i| \leq 1$ minutes) at all stops;

R_{Tot} = total number of runs;

- Frequency Variability (Regularity), expressed as standard deviation of average frequency:

$$FV = \left[\sum_{i=1, \dots, n} (x_i - AF)^2 / n \right]^{1/2}$$

where:

n = number of passages;

x_i = punctual frequency;

AF = average frequency;

- Frequency Reliability, as % of runs meeting the scheduled frequency:

$$FR = 1 - R_F / R_{Tot}$$

where:

R_F = number of failed runs;

R_{Tot} = total number of runs;

- Cancellation runs, as % failed runs:

$$C = R_C / R_T$$

where:

R_C = number of cancelled runs;

R_{Tot} = total number of runs;

- Buffer Index, as accumulated delay time indicator

$$BI = (TT_{95} - M) / M$$

6.3.5 Actual experience

Within the COST research, sample reliability analysis has been carried out on some European BHLS lines; particularly in Madrid (ES), Trans Val de Marne (FR) and Manchester (UK). These three cases deal with high frequency transport systems but the results of the analysis have been different because of the different monitoring systems of the base measures and the statistical process applied. The control of the reliability has proved to be more precise and targeted in the case of the French BHLS line (TVM); in fact the data are collected and processed in “real-time”, so that corrective actions are possible on the running diagrams of vehicles (commands operated by a Supervision Centre) in order to avoid undesired delays or creation of “trains of buses”.

The six indicators selected for the TVM service were analyzed. Specifically, the indicator of punctuality (PT) shows that the percentage of runs on time at each terminal (arrival/departure) is enough high (about 70% on data relating to the whole month of February 2009), while the punctuality indicator PS indicates that the % of the runs on time along the line is very low ($PS < 10\%$); this last condition is very limiting as this concerns the BHLS scheme.

Considering the Frequency Variability indicator (FV), one can see that the regularity of the service changes in relation to the direction and considered time range (AM PEAK, PEAK INTER, PM PEAK); in particular, the 16:00-18:30 period is the most affected time slot and, in general, the highest values are at stop interchanges with regional trains RER A and RER B (standard deviation 3.5÷ 4.5 minutes). The reliability of the service changes in relation to the direction and considered time range; particularly, the most concerned time slot is again the 16:00-18:30 period in one direction ($FR < 45\%$). The FR indicator is quite low in both directions as the comparison was made between the intervals of “scheduled time” and “real-time”, rather than the “commanded time” operated by the Bus Operation Centre. The study of the time system, during the months of 2008, shows a high value of reliability of the system related to cancellations: C is always $> 97\%$. The BI in each direction of travel is just under 20%; this means that the user has to increase his travel time (of about 20%) in order to get on time arrival in 95% of cases.

User requirements and procurement processes: a case-study of an AVM system

7.1 Introduction

The rapid development of Information Communication Technologies (ICT) for the transport sector (also referred to as Intelligent Transport Systems - ITS) in the last few years has enormously increased the technological offer that transport managers and decision makers have to tackle when planning, designing and implementing the introduction of new systems into the existing transport infrastructures/operational chain. Within the various operational procedures and resources of a Transport Company, the implementation of an AVM system - Automatic Vehicle Monitoring (also referred to as “Support System for Transport Services Operation” in the technical literature) - is a useful “training” example to discuss this issue. Indeed the implementation of AVM systems involves a number of problems that the Transport Company has to address and solve in order to achieve successfully its technical and economical objectives. In the following, detailed references will be made to such systems. When appropriate, the specific considerations made as regards AVM systems will be generalized.

The procedure for implementation of AVM systems (and more generally, of other infomobility systems) ranges from the definition of the main objectives and the identification of the technical and organizational requirements to be included in the bid, through to the procurement process (see Sections 7.3 and 7.4), system implementation, system running, testing and assessment, the definition of related operational procedures

and the required changes in the organization model. All of these phases are mutually interdependent and an effective approach in each of them is an essential prerequisite to ensure the protection of the investments that are necessary for the system¹. A feasibility study, in this scenario, is far from being a mere “loss of money” (as it is sometimes perceived); rather, it represents a fundamental phase in which a correct approach for the overall procedure is identified and the steps to ensure the quality of the investments are detailed.

From the technological point of view, during the feasibility study, the buyer/user (i.e. the Transport Company) should identify the real objectives of the system, the functionalities and the supporting architecture, as well as a suitable implementation plan (structured in “phases” and “milestones, see Section 7.3) that sets the timetable for system implementation and guarantees the effectiveness of the results (for each phase). Also, the impacts of the system on the organization of the Transport Company must be deeply investigated. From the management point of view, the study will have to identify the contractual conditions required to guarantee the interests of the buyer/user during the implementation and delivery phase.

Ignoring the “easy-to-get” benefits that are often promised by the marketing, Section 7.2 presents an in-depth analysis of the progress and achievements of AVM deployment across the Italian and European market highlighting a number of problems related to the implementation of such systems (strong delays in the timing plan, partial achievements of the expected performances, etc.). In this context, the relevance of a feasibility analysis, able to identify the milestones and the necessary conditions to perform an effective assessment of the different implementation phases can be easily understood.

Section 7.3 presents a central issue in the overall process of implementation and deployment of advanced ITS solutions for transport applications: the tendering phase for the acquisition of the required ICT systems. Together with the following section on procurement (Section 7.4) it provides a discussion of the key issues involved in the complex process that, starting from the knowledge of the needs and objectives that the ITS solution should meet (Section 7.2) will lead to the acquisition proper and to the effective roll-out and start up of the technologies concerned. Finally Section 7.4 describes an innovative methodology for the evaluation of the different offers in response to a Call for Tender, that is one of the most critical phases of the overall procurement process of Intelligent Transport Systems (ITS) in the Mobility and Transport sector. In general, the Contracting Authority has a dual role in this respect. On the one hand, at the level of Call for Tender and procurement documentation, it shall specify the modalities of bid presentation by the participants; on the other hand, it should set up a methodology which would allow evaluators to read, analyse and evaluate the offers of the different

270 1 A generic assessment of the benefits of user requirements analysis is provided by Finn (2004).

participants to the tender in an objective and transparent manner. In particular Section 7.4 provides a general structure – a sort of backbone – for an evaluation methodology, which should be customised to the different requirements of the specific Call for Tender defined by the Contracting Authority.

7.2 User requirements from an operator point of view

G. Ambrosino, C. Binazzi, S. Gini, A. Iacometti

7.2.1 Objectives of AVM system implementation

The current experience and market trends present AVM systems as the main “tool” to ensure a high level of quality of the transport service. Indeed AVM systems enable transport managers to act on the overall production lifecycle as regards:

- Service programming, based on the availability of updated actual travel time/speed, passengers data, etc.;
- Service control, based on real-time information and transport network monitoring;
- Service operation, based on the management of irregular service conditions (traffic, unexpected events such as strikes, roads deviations, etc.).

These elements show clearly that AVM systems are more complex than the basic AVL (Automated vehicle Location) systems, able to perform mainly the location of fleet vehicles on the network².

The objectives and related requirements and needs of a Transport Company achieved through the implementation of an AVM system can be usually found to include the following:

For the Transport Company:

- Collection of information related to travelled trips/kilometres;
- Driver safety (through voice communication, alarms transmission and dispatching of pre-coded messages);
- Control and management of fleet regularity through the dispatching of automated control events (i.e. starting time at bus stops/terminals) and semi-automated operations (trips limitation, added buses on the network, etc.);
- Optimization of service planning based on comparison between actual and scheduled trips;
- Monitoring of buses, including diagnosis of vehicle state, failures, fuel consumption, etc.;

² An hierarchy of detection leading to greater sophistication can be described by the following typology: Automatic Vehicle Identification - Automatic Vehicle Locationing - Automatic Vehicle Monitoring.

- Optimization of the use of on-street control personnel, reducing the overall monitoring task and concentrating it where really necessary; and
- Communication of pre-trip user information (through direct phone calls / web portal) as well as of on-trip information on board or at bus stops/terminals.

For the Users:

- Increased passengers safety, by the dispatching of on-board alarms in case of emergency situations;
- Enhancement of service quality perceived by the users/passengers, mainly as a result of the increased regularity;
- Pre-trip real-time information (web services available through Internet portals, on mobile phones, etc.) (see sections 2.3 and 2.4);
- Real-time information about the expected arrival time of buses displayed at bus stops/terminals; and
- Real-time information on-board.

For Statutory Authorities:

- Monitoring of service indicators (collection of data, comparison of computed indicators with target values, etc.) in order to define penalties/prizes.

Such objectives stem from the requirements of Transport Companies but some of them also from transport regulations and standards set by European, National and Local Authorities. For instance, in Italy, Local Authorities (Provinces/Municipalities and equivalent bodies) are in charge of defining the characteristics and requirements of public transport services, and of controlling their operation (collection of travelled trips/kilometres, deviations between operated and scheduled service, irregular events, etc.).

During the feasibility analysis, these objectives must be taken into account in order to come to an appropriate definition of the technical requirements, the functionalities and the supporting operational scenarios that the system has to guarantee. From the definition of the operational scenarios one can identify the level of the impacts on the organization and procedure related to the implementation of the system. The different objectives must be evaluated in the framework of a particular service scenario (metropolitan, urban, suburban, rural area) as the relevance of a given objective can be high in relation to a type of scenario, and significantly lower with respect to another one (see Chapter 6).

7.2.2 AVM Architecture and level of complexity

Figure 7.1 shows a general AVM architecture based on the following main components:

- Control Centre, accessible via LAN (internal user/operator), VPN (external user, outside the LAN) or the Internet (Statutory Authority, for instance with the goal to carry out

The complexity of an AVM system is not only related to the performance of technological components but also, if not mainly, to the impacts on the overall organization of the Transport Company and on the management of the operational procedures carried out by the technical staff. Such impacts may relate to various levels:

- Control Centre, related to monitoring and control procedures, management of irregular service conditions, interactions with other departments/sectors of the Company (drivers, maintenance, planning, quality control, etc.) and related operations;
- Communication networks, related to different types and technologies that have to be managed (GPRS/GSM, LAN/WAN, W-LAN, TETRA, etc.);
- Depots, related to operational procedures to be adopted to guarantee the state of efficiency of all vehicles that are involved (on a daily basis) in service operation (maintenance of on-board devices, state of transmission between the vehicles and the Control Centre, replacement of vehicles with faulty on-board devices, etc.);
- Vehicles, in terms of operational procedures that the drivers must carry out to use/interact with on-board devices (service initialization, voice communication, notification of events to/from the Control Centre, etc.); and
- Roadside users' information systems (panels, etc.), related to the maintenance of devices, monitoring of the performance level, etc.

The impacts involved in the implementation and management of an AVM system are so inter-related with the different sectors of the Transport Company that in most cases it becomes necessary to rethink its organizational and operational structure. Furthermore, new critical issues to be solved are generated, the most relevant of which are:

- Co-ordination of the different activities related to the systems implementation process;
- Management of contractual issues with the IT provider;
- Availability of technical profiles related to system functionalities and procedures (Control Centre, depots, etc.);
- Operational profiles related to both the utilization of the system (drivers and Control Centre personnel) and to its maintenance;
- Operational actions related to emergency management (on-board security of passengers and drivers); and
- Operational procedures related to the “day-to-day” management of the system.

7.2.3 The Implementation Plan

In addition to the issues discussed above, the definition of a feasible implementation plan represents another critical element of the process of AVM acquisition and deployment within a Transport Company. Indeed, this requires a careful monitoring process to be carried out by the Transport Company in order to successfully achieve, within the planned time, a system able to fulfil all the operational and functional requirements.

The implementation plan must be defined in the feasibility study in terms of phases, results to be achieved (and verified) for each phase. The definition of the implementation plan should take into account all the operational/organizational constraints of the Transport Company (availability of the vehicles to be installed, service operation, etc.) and should be formulated in such a way as to guarantee the buyer the provision of a clear timetable and criteria for the verification of implementation. This will be achieved properly through the definition of various phases, starting from a “prototype system” (of limited size) and ending with the release of the final system: each phase will represent a step of the implementation and will end with a clearly defined testing procedure. Each step will enable the buyer to verify progressively the level of fulfilment of the results obtained in the phase, compared to the corresponding target objectives (functions, performances, etc.), solve the problems step by step and minimize the operational efforts in the start up of the system. Furthermore, the restructuring of the organizational model and operational procedures should be also carried out gradually. From the administrative standpoint, the definition of such an implementation plan will enable the buyer to avoid binding the acceptance of the complete system with the very final testing, allowing some intermediate evaluation steps and leaving room for corrective actions in case any problem is detected along the implementation path.

In detail, each phase of the implementation shall be able to ensure:

- The monitoring of the performance indicators defined in the bid;
- The control of the degree of system fulfilment compared to specific requirements defined in the bid;
- The monitoring of the organizational procedure and the evaluation of the efficiency and effectiveness of the new model;
- The possibility to modify more easily the next implementation phase;
- The application of penalties related to the lack of fulfilment of the system, compared to the requirements/indicators defined in the bid (delays, functionalities, performance); and
- The possibility to opt for contract termination, based on the modalities defined in the bid.

For each phase defined in the implementation plan, the fulfilment of the system compared to the objectives/performance (defined for each phase in the bid) can bring about the payment of the related instalment to the IT supplier.

In the feasibility study, the lack of a clear definition of the implementation plan is often responsible for major delays in the implementation process itself. The increased operational/organizational complexity of the process, together with the delays in the actual implementation, often result in the decision of the buyer to give up on some requirements that are nevertheless specified in the bid (and some of these may also

relate to important features and characteristics of the desired system). In many cases, this brings about a continuous reduction of the expected results of the system, in terms of functionalities, operational requirements and performance. An analysis of available experience in AVM implementation shows that, very often, this led to “limited” systems (in terms of functionalities and performance) that probably would have been realized with higher capabilities and at lower costs (investments, efforts, resources) should these issues have been properly identified and tackled in the feasibility study.

7.2.4 The Feasibility Study

As discussed above, before starting the tendering procedure for the purchasing of an AVM system, the buyer should carry out a thorough feasibility study aimed to size the system (and its implementation) to the specific needs of the Transport Company. The relevance of the feasibility analysis implies the need to allocate the required time and resources for the study. Indeed the feasibility analysis is too often underestimated and is seen by the buyers as a poor use of time. Or, even worse, in case public funding is available, as a way “to get (or not to lose) funding”.

The most relevant issues involved in the feasibility analysis can be summarized as follows:

- Identification of the objectives related to system implementation;
- Identification of the functional requirements of the system, based on detailed modalities of achieving each objective;
- Identification of the operational procedure related to each functional requirement;
- Identification of the size of the system (in terms of number of devices, typology of components, etc.); for instance, selection of the long-range communication network based on specific and general requirements of the Transport Company;
- Identification of the costs of investment, based on the required functionalities;
- Evaluation of organizational issues in order to identify the required changes in the implementation of the system;
- Identification of the operational costs related to the implementation, management and maintenance over time of the system, based on the required functionalities, related operational procedure and changes in the organizational model;
- Definition of the implementation plan; and
- Definition of the main administrative issues to be considered in the set up the call for tender.

Costs/benefits analysis and trade-off decisions are basic tools of the feasibility study. As an example, we can consider the selection of the long range communication network:

- A private network (eg. TETRA) involves higher costs of implementation and maintenance, higher costs for the management of the radio frequencies and time to purchase

the channels, but enables the Transport Company/buyer to get and operate its own network. Costs and time relate to the determination of the number of channels and radio stations, the identification of suitable locations for the installation of radio stations and the definition of time and costs related to land purchase, as well as the analysis and definition of the technical solution to connect the Control Centre and the radio stations;

- A public network involves no costs for implementation and maintenance, as well as lower costs for the management of the service, but it doesn't allow the Transport Company to obtain its own telecommunication infrastructure and get full control over it.
- A TETRA private digital network offers the Transport Company/buyer an opportunity to meet the overall communications requirements while also playing the role of Telecommunications Provider in the urban environment (also related to other public transport services such as tramways, etc.).

7.2.5 Costs of the system

Costs are closely interrelated with the technical, functional and operational requirements that are to be met by the system. For instance, if service optimization against the actual transport demand is the primary objective of the Transport Company, then data collection and the estimation of service performance indicators to be carried out also through off-line methods is the most important requirement for the system, rather than ensuring high performance levels in real-time monitoring and control capabilities (vehicle location, polling modalities, etc.).

On the other hand, if the primary objective is service control and real-time management, the specification of requirements must be focused on the modalities of vehicle location, on the procedures to generate the actual arrival time of vehicles at bus stops/terminals, and on the performance of the communication network.

Different requirements bring about different investment and maintenance costs depending on various factors, including the type and technical requirements of the devices, the functionalities of the Control Centre, the database structure, the procedures related to system installation and maintenance, etc. In addition to the costs of implementation, the operational costs must also be evaluated. These relate mainly to the costs of the personnel operating the Control Centre (number of operators and related reallocation of work). The presence (full-time, part-time, "on demand", based on the notification of events carried out by the system) and the number of operators are strictly related to the relevance of monitoring and regulation activities, in terms of objectives/requirements. Apart from the personnel in the Control Centre, the Transport Company shall also take into account the costs related to the set up of the organizational structure required to

support the IT provider and, after successful commissioning of the system, to perform the day-to-day operational management.

In order to provide an example, a medium size Transport Company (15 lines, 100 buses, urban service) should set up and allocate a job staff involving at least the following resources/professional figures:

- 1 responsible for the overall AVM technical development, who directly interfaces with the system provider and lead the team;
- 1 responsible for the technical infrastructures (on-board devices, panels, depots, etc.);
- 1 responsible for system functionalities and software products/solutions (Control Centre hardware and software, etc.);
- 1 responsible for the communication network(s); and
- 1 responsible of maintenance activities at each depot.

Specifically, the following main tasks should be taken into account:

Control Centre

The person responsible for systems functionalities and software applications will be in charge of the organization, management and support of operators, monitoring of system status and assessing the overall system quality (supported by automatic diagnostic tools). He or she should provide an adequate training to the operators in order to master the operational procedures in case of failure. Furthermore, the operators should be able to provide “first aid” as regards maintenance procedures. Generally, each operator should be able to understand the impacts of system failure and to start the recovering procedures, or to contact the responsible person in charge of the Control Centre.

Drivers

Their role should include the capability of performing the operational procedures to interface the on-board terminal and the operations to be carried out in case of failure or irregular conditions of the equipment. Therefore, a Handbook on operational procedures should be provided to the drivers and updated in accordance with system upgrades and evolution.

Depots

The management of the operations in the depots is one of the fundamental tasks to ensure the appropriate numbers of equipped buses are available for service operation (at least on the lines monitored by the AVM system). Usually, the personnel performing vehicle operation control are responsible for this task, co-ordinated by those responsible at depot level.

278 Those responsible at depot level are also responsible for supporting the maintenance service provided by the IT supplier. Operational costs are strongly affected by the de-

sired level of service (in terms of time of intervention and system recovery, presence of permanent logistic/operational team, preventive/corrective maintenance, extraordinary maintenance on call, assistance by phone, etc.). In some cases, first-level maintenance operations (e.g. substitution of on-board devices) can be carried out directly by the personnel of Transport Company. Last but not least, operational costs are dependent also on the value of performance indicators that are required to the system. Indeed, all these issues have relevant impacts on the maintenance service that the IT supplier must provide. Thus the performance indicators must be defined accordingly by the Transport Company/buyer in the tender.

7.2.6 A case study: the Italian market

The issues discussed in previous sections reflect the current situation in the AVM market, where the systems supplied sometimes do not fully meet the real needs of the Transport Companies. If we take the Italian market as an example, a main emerging issue is the fact that the suppliers themselves are often found unable to effectively play their system integrator role, at least to the extent required by the complexity of the integration and implementation of an AVM system.

The AVM market is in continuous evolution showing a varied situation in terms of types and size of IT and solutions suppliers. Often, one can see a rapid growth and failure of IT suppliers playing different roles in terms of mission, dimensions, finance and reliability. On the one hand, larger IT providers have the capability to afford unanticipated difficulties and longer delays in the implementation path (due, for instance, to unsatisfactory results at the testing phase) but often they do have strong product oriented policies and are less keen to tailor the features of the system to the real needs and requirements of the Transport Company. On the other hand, a small/medium-sized IT supplier could provide a more flexible and effective response to the needs of the Transport Company, in terms of stronger attitudes to system customization. However, in many cases they happen to lack the financial resources required to face the length and burdens of the planned implementation plan (and even more the frequent delays).

Furthermore, AVM technologies and systems represent a niche market in Italy (due to the overall number and size of public transport companies) and a number of companies are too small to afford the investment required by the AVM technologies or approach the AVM market only with a marginal commitment. In many cases, the implementation of the system is often shared among different providers.

As it turns out clearly from market analysis, the overall risk of the implementation of an AVM system lays completely on the side of the Transport Company. Indeed it is for the transport operator to cope with the impacts of technology (at economical as well as operational level) and to provide effective answers to the needs of both Public Authorities, who are defining and tendering public transport services, and the users/

citizens, who require the provision of services with the appropriate quality levels. A sort of vicious circle may thus be growing, as the complexity of the implementation process can generate unclear situations about the responsibilities among the Transport Company, the buyer (if different from the Transport Company) and the supplier of IT systems. This confusion leads to delays in the implementation time and to the lack of fulfilment of the requirements and objectives of the tendered systems.

Transport Companies should see the implementation of an AVM system as “a global service”. The analysis and definition of all the fundamental issues related to this global service (type and level of service) must be carried out in the feasibility study, in order to ensure that all the requirements are covered, well understood and completely defined in the tender. Based on this, the Transport Companies will then be able to focus on the related operational and organizational issues.

7.3 General considerations in the tendering phase

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In any Call for Tender for the acquisition of an advanced technological system (or service) the Technical Annex is a fundamental reference and the final output of the definition of a system’s technical and functional specifications, on the basis of the identified user needs and objectives. The administrative documentation shall follow this specification, and should be structured as flexibly as possible into elements (articles) that link some key technical and functional specifications of the system with the tender evaluation process, contract definition and the system implementation, testing and maintenance process.

From the technical point of view, the approach leading to the system functional specifications should be focused to the identification of the real requirements of a Transport Company on the basis of the service and users’ needs. It is furthermore necessary to identify the proper scale of the system (in relation to the number of users/operators, territorial infrastructure location, vehicles, technical equipment, etc.) rather than on the technical features of the single components (e.g. location precision). The requirements on technical performances of the components should be limited to specific features, the presence of certifications (e.g. electromagnetic compatibility, electrical safety, resistance to bumps and vibrations, compliance with automotive standards, etc.) and environmental features (temperature, humidity, etc.).

Applicants should be required to present their offer (technical as well as economic proposals) in a “structured way” that must be clearly indicated in the bid documentation. This is the only way to receive proposals/offers that can be later compared to each other (and with the requests of the Technical Annex) during the evaluation through a common methodological approach (see Section 7.4 for discussion of the evaluation process).

It is important to underline that the tendering process does not end with the evaluation of the proposals: after this phase two more steps must be managed. The first step is the **negotiation phase**, during which the adequacy of the technical solutions described in the proposal (i.e. the one awarded with the highest evaluation score after the technical and economic evaluation; see Section 7.4) must be assessed on the basis of previous experiences and of the time schedule / resources / costs declared by the applicant for the implementation, testing and start up of the system offered. Also, any inconsistency between the “winning” offer and the requirements defined in the Call for Tender must be identified, analyzed and solved. In this phase, some further details to better understand the compliance of the proposed solution with the requirements might be eventually requested to the applicant/participant and further negotiated.

The second step is the definition of the **contract proper**. In this phase, a detailed view of the components of the system must be defined together with the associated Implementation Plan – in terms of phases, milestones, timing of payments related to specific outputs that must be tested and approved by the purchaser. Performance indicators must be listed, together with the values (“targets”) to be achieved by the system in the different stages of the implementation process – testing of each intermediate phase of the implementation, final testing of the system, maintenance. Penalties must be defined related to delays in the realization of the systems (milestones for each phase) and unsuccessful performances compared to target values of the indicators. All such indications should be already defined in the administrative documentation of the Call for Tender and translated directly (with the necessary updating) to the contract.

Following these general guidelines, the tender must be seen as the process to receive proposals as closely “tailored” as possible to the purchaser needs and objectives and, at the same time, it should be able to provide all the administrative “tools” to allow monitoring of each phase of the implementation separately, without any constraint arising from the acceptance of previous phases.

Based on extensive monitoring of relevant Calls for Tenders and purchasing processes in Italy over the last decade for ITS systems, the remainder of this section will provide some suggestions related to the structuring of the administrative tendering documents in order to successfully achieve the objectives listed above. Specifically, elements will be provided related to the definition and specification of:

- the size and components of the system, and the activities required for system implementation, integration, testing and start up;
- the structure and general guidelines for the presentation of the technical and economic proposal;
- the criteria for offer process evaluation;
- the modification of the economic value of the tender in the contract;
- the Implementation Plan, milestones and related payments;

- the procedure to start and end the installation activities;
- the testing procedures; and
- the penalties and options for termination of the implementation.

7.3.1 Size and components of the system and related activities

Overall, this set of articles shall define:

- the list of all components of the system (and related quantities); and
- the list of activities related to the implementation, integration, testing and start up of the system – i.e. the definition of detailed functional and technical systems specifications, installation of devices, integration with other systems already running on-site, assistance during system start up, maintenance, release of technical documentation, training of the involved personnel.

System components

Each component/device of the system must be clearly identified and the related quantity must be reported. A generally useful practice is to declare the minimum quantity of the required components in order that the participant could have the possibility to offer the required quantity.

As regards the definition of the architectural platform, there are usually two possible options. In some cases, it may be desirable to provide the applicants with a reference architectural typology and technical requirements. In other cases, it may be more appropriate to leave the applicants free to offer what they consider as the best solution in relation to the requirements of the tender. In both cases the purchaser shall include the indications required to guarantee the technological and economic investment in case of future extension/integration of the system.

As regards the software components included in the supply, care must be taken (usually in the administrative documentation) that any software licence is released without any temporal limitation and with the price not depending on the number of peripheral devices), to avoid further additional future costs.

Activities related to system implementation, integration, testing and start up

The release of a detailed definition of the technical and economic specifications of the system is required as the first activity after the signature of the contract. This is a fundamental activity to be required from the contracted supplier and should provide full evidence of the capabilities of the offered system, in terms of functionalities and operational procedures, of meeting the requirements set by the user.

All installations must be realized in accordance with the regulations on safety, security and technical requirements defined by the national and international standards. An appropriate installation is a fundamental prerequisite and a preliminary activity to ensure that the system will run as described in the Technical Annex.

Any customization of the software and of the operational procedures must be clearly indicated and included in the tender as activities that the supplier will have to provide. This will guarantee the purchaser that the offered solution will be able to meet the requirements to the maximum possible degree; this is of particular relevance, for instance, in relation to the integration of the system with the other systems already implemented. These activities are often underestimated by the applicants when they define their proposal.

The release of the technical documentation (users' manuals, system architecture and scheme of components connection, certifications, etc.) and the training of all the personnel involved in the start up, management and maintenance of the system is also an activity that is often given less attention by the applicants than necessary for a smooth and effective start up of the system. In order to ensure this, the tender documentation must then include clear statements related to the on-site assistance the contracted applicant shall deliver to solve any issue related to the installation, configuration and start up of the system. The maintenance of the system must be included in the tender and clearly defined in terms of service level agreements (SLA), time of recovery (different from time of on-site intervention), on-line assistance (e.g. remote assistance, by phone, etc.) and resources available.

7.3.2 *Presentation of the technical and economic proposals: Structure and Guidelines*

Infomobility systems often imply technical solutions comprised of several sub-systems, components and devices. An AVM system, for instance, involves various elements including: technologies (network architecture, long-range and short-range communications systems, database infrastructures, Internet and on-line access interfaces, etc.), algorithms, control and management procedures (scheduling of vehicle arrival times, service management, etc.), operational procedures (operators support, vehicles – Control Centre communications, management of service initialization, etc.), installation activities (on-board devices, Control Centre, depots, etc.). All such issues are fundamental elements having strong impacts on the overall capabilities, performance and effectiveness of the selected system, and therefore must be carefully taken into account during the technical evaluation phase. Indeed technical proposals are sometimes redundant in this respect or (the opposite) too general, without providing specific functional and operational descriptions. They are often formulated though a poor customization of already available descriptions, not well integrated and harmonized together, often developed by the commercial departments of the company with little involvement of the technical and assistance personnel that will be in charge of the implementation and start up of the systems.

As regards the economic part of the offer, it is important to provide the applicants with a clear structure to enable them (or indeed “force” them) to organize and present 283

their quotation in a clear and unambiguous way. This can be effectively and easily done by providing a structured schema for costs declaration (e.g. a Table of Costs) that the applicants shall fill-in reporting their quotations for each sub-system, component and device (the optimal sub-division of the system being eventually different in relation to the specific requirements of the tender) and for each activity (management of implementation, services, maintenance, etc.). Such a table will provide the purchaser with a fundamental support during the negotiation phase.

Structuring of the technical proposal

From previous sections, the complexity of the technical evaluation of ITS proposals should be clear. The relevance of defining a common structure and providing the applicants with some guidelines for the presentation of their offers should be clearly understood. In the administrative part of the documentation of the tender, a specific section shall be included defining how the system should be described by the applicants with reference to a common scheme. The scheme will help the evaluators in the analysis of the different features of each sub-system/device and in assessing the level of compliance of these with the requirements defined in the Technical Annex.

In order to describe a possible structuring of the technical proposal (i.e. its main required elements) we will take as an example the key sections of the tendering of an AVM system. The example will provide a conceptual basis that will be easily generalized to other tenders related to infomobility systems and ITS solutions.

Overall, the following key technical sections could be considered:

- *Technical, functional and operational specifications.* This section should address the overall system as well as each sub-system, component or device. Operational specifications are very relevant and their importance should be stressed in the requirements of the tender. For instance, it should be mandatory for the applicants to provide information about fundamental operational parameters such as the Mean Time Between Failure (MTBF) for each component of the system. In case of use of public communications networks (i.e. UMTS, GPRS, GSM connections) the applicants must provide clear evaluations as regards the amount of traffic data generated by the communications between the components. This information will support the purchaser not only in the evaluation phase but also in the definition of the contract with the communications service provider.
- *Installation activities and logistics support.* Applicants should provide an estimation of the number of people involved in the installation activities. This is an important requirement that should allow the purchaser to assess the economic viability of the offer in this respect, as this issue is often the cause of unforeseen costs or delays during the installation phase.
- *Implementation, integration, start up and testing.* Applicants should provide a clear time plan covering all these key phases. For each phase, a description should be provided of

the different macro-activities, milestones and responsibilities. A particularly relevant element is the estimation (and description) of the support that the applicant will need from the purchaser for each phase/activity, in terms of human resources (e.g. time availability of the project manager, technical responsible, reference personnel, etc.) and logistics (e.g. recovery area for the materials, area to carry out the installation activities). A Gantt chart could be required in order to better display and assess the timetable during the evaluation phase.

- *System testing procedures.* The procedures and time plan for testing and evaluating the system in all its components, as well as the required interfaces with the other systems, should be provided. The testing will be performed several times by the purchaser and with several objectives and degrees of evaluation of system capabilities; usually, after each phase and at the end of the complete implementation.
- *Quality plan of the realization.* A description of the methods and measures followed to ensure the quality of the implementation process and of its final results.
- *Assistance and maintenance of the systems.* On the basis of the requirements indicated in the Technical Annex, the applicants must provide clear indications about the service level agreements (SLA) for each requirement. Applicants shall be also required to indicate the number, professional skills and role of the technicians involved in the activity and describe the proposed services (assistance by phone, etc.);
- *Training and technical support.* A suitable plan should be provided as regards the training and technical support of the people that are involved in the management of the tendered systems (management, co-ordination/control, drivers, etc.). Of particular importance is the level of assistance that the applicants shall guarantee during the start up of the system, which shall be fully described and quantified;
- *Technical documentation.* A complete list and description of the technical documentation and users manuals provided with the technical supply;
- *System components and devices.* A complete list should be provided and, for each component/device, the applicants shall provide the number, type, brand, technical features/performances and the references of the systems (already in operation) in which each component/device has been installed and integrated; and
- *Authorizations.* A complete list of the authorizations required for the implementation of the systems, if any – i.e. in an AVM system: power supply for roadside user information devices. Particularly, applicants must be required to carry out and fulfil all the concerned administrative procedures; e.g. requesting and obtaining the authorizations from the concerned Authorities, etc.

Furthermore, the applicants will be required to add to the technical description of the proposal any useful illustrative supporting documentation such as photos, diagrams, system layouts, etc. These shall include, for instance, photos and layout of the offered 285

components/devices (e.g. in an AVM system: drivers terminal, display for on-board users information, display for roadside user information, etc.), pictures of the software users interfaces in the Control Centre, movies/photos/schemes illustrating the operational procedures required for the maintenance of the system, etc. Besides, the applicants shall be given the freedom to include any additional section to what is strictly required by the purchaser.

Summary and comparison tables

In order to standardize and facilitate the evaluation phase, the above main features should also be presented in a summarized and harmonized way. A set of formatted tables shall be defined by the purchaser that will focus on each sub-system/device of the offered system. Each row of the table will relate to a specific component/functionality of the system, and should match a main requirement defined in the Technical Annex. Applicants shall be invited to fill in the tables in a synthetic and comprehensive way, eventually including references to specific sections of the technical proposal for more information.

Only this way will the purchaser be able to obtain technical proposals whose structures will be matching the requirements set in the Technical Annex to the largest possible extent.

7.3.3 Definition of evaluation criteria

The evaluation criteria included in the administrative documentation provide reference elements – and constraints – for the analysis of the offers and for the judgments expressed by the Evaluation Commission. It is therefore important that the general elements and views provided are developed to the right extent and in a proper way, in order to reflect correctly the goals, expectations and preferences of the purchaser as regards the balance between technical quality and economic costs of the system. On the other hand, the lines provided must be general enough to leave the Evaluation Commission the necessary freedom in defining its own detailed evaluation schemes. Such detailed schemes will follow the general indications provided in the administrative documentation of the tender, while, at the same time, will be customized and tuned so as to yield, finally, evaluation tools that are effective and operational.

To this end, the Evaluation Commission shall achieve the appropriate formulation of the schemes on the basis of the structure and the tables provided in the article describing how the proposal must be presented by the applicants. An evaluation methodology will be defined on the basis of the first level structure and tables, as well as on the detailed tables at the secondary level. Generally, the number of levels shall be chosen time by time, based on the specific goals and characteristics of the tender (refer to Section 7.4).

Technical vs. economic evaluation factors

286 In order to achieve the most suitable evaluation system, from both the technical and

economic point of view, the most effective approach is to adopt a scheme based on the notion of “virtual costs”, able to tie together the technical and economic values of the concerned system and to balance in a convenient way the technical quality of the solution and the economic cost of the investment made by the purchaser.

An emphasis on technical evaluation factors has the clear goal of helping the purchaser to select technically reliable partners. This is a general aim for the purchaser, however it may have a special relevance in any situation when IT suppliers try and maximize their market opportunities and contract acquisitions up to levels that exceed their real capabilities, and mostly at the margins of their core market. In such cases, stronger technical factors (e.g. higher technical standards, higher level of service, number of running systems, etc.) may help the purchaser to avoid selecting and contracting companies whose core business does not really include the tendered systems. This may happen, for instance, during market contraction phases, when many “newcomers” may respond to the tender mainly for market enlargement strategies, which is often indicated by a total lower cost for the offered system trying to balance the lower technical value of the proposal.

Table 8.1 provides an example of possible balance between technical and economic factors, with a stronger emphasis of technical elements.

Evaluation Criteria	Value %
Technical Factor	Range from 60 to 80
Economic factor	Range from 40 to 20

Table 7.1: Examples of balance between technical and economic factors

One way to increase the relevance of technical evaluation over the economic value of a proposal can be given by the following formula that might be included in the administrative documentation of the tender:

$$B_n = 70 \left(\frac{V_n}{V_0} \right)^2$$

Where:

B_n = value assigned to each technical proposal;

V_n = vote assigned by the Evaluation Commission to each technical proposal;

V_0 = highest vote assigned by the Evaluation Commission in the technical evaluation.

In order to strengthen the evaluation process, an important choice for the purchaser is to assign to the “level of experience” of the applicants – i.e. number of previous implementations of the same type of the tendered system, progress of the implementations, dimension and technical/functional features of the implementations, etc. – a prominent role in the overall evaluation scheme. This can be done adopting the parameter at the “first level” of decomposition of evaluation criteria (refer to Section 7.4).

However, one should note that national regulations and practices may impose particular constraints in using “level of experience” as one of the evaluation criteria during the tender. For instance, the current (2008) regulation governing public tenders in Italy (D.LGS. 163/2006) imposes a quite rigid choice: when this is adopted in the pre-qualification phase as an operational criterion to select the applicants for the tendering proper, the purchaser is not allowed to take “level of experience” as one of the elements of the evaluation process. Thus, the purchaser has to consider carefully the most effective use of this evaluation category – i.e. whether to use it to narrow the number of potential applicants down to those really experienced, or as a main element to be used during the assessment and evaluation proper of a larger number of proposals.

Structuring “first level” evaluation criteria

A good compromise as regards the level of specification of the technical evaluation criteria to be included in the administrative documentation is to limit the breakdown process to a “first level” decomposition. This will enable the Evaluation Commission to define the secondary level of criteria on the basis of the tables provided for the presentation of the proposal (see Section 7.4).

As an example, the following list provides a first level decomposition of technical evaluation criteria (the example relates to evaluation of an AVM system, but can be easily generalized):

- 1) Technical/Functional value of the proposed solution;
- 2) Technical Value and assistance and maintenance service time;
- 3) Quality of the proposal.

Under the third first level criterion, the following evaluation elements can be further identified: 3.1) implementation timetable; 3.2) system testing and start up; 3.3) description of installation activities; 3.4) description of testing procedure(s); 3.5) human resources involved in the implementation, testing and start up of the system (number, role); 3.6) quality plan (quality certifications are evaluated under this topic); 3.7) training activities; 3.8) description of technical documentation.

Once again, it is important to note that the choice of these criteria remains totally with the Purchaser: depending on the specific goals and requirements of the tender, some of the “second level” criteria could be promoted to the “first-level” and vice versa, in any case this must be clearly stated in the bid documentation.

As an example, the range of the technical “first-level” criteria can be assigned as reported in Table 7.2 below.

Two-step tendering and evaluation

288 Several tenders that took place in Italy over the last years (mainly for the acquisition of AVM systems) have adopted a two-step approach for the tendering and evaluation of the

“First-level” Technical criteria	Value or Weight %
Technical/Functional value of the proposed solution	Range: 60 to 80
Technical Value and time of the assistance and maintenance service	Range: 15 to 30
Quality of the proposal	Range: 5 to 10

Table 7.2: Ranges of “first-level” technical criteria

offered systems. This involved a first offer, selection and evaluation of a prototype system – often meeting only the core system requirements and still lacking any further development and customization to the more specific requirements of the tender – and a second offer, evaluation and selection of the final system, with the detailed economic quotation for the fully developed system meeting all customer requirements and needs.

In such cases, the evaluation of a demonstration (prototype) system was included as a “first level” element of the overall evaluation scheme. This related to the results of some system evaluation sessions carried out for a limited period of time – for instance, a specific day when applicants were required to demonstrate their systems in operation for a few hours.

The aim of such an approach is to achieve an operational and effective test of the offered technologies and systems, in order to be able to evaluate their basic compliance with the key requirements and expectations for the tender, their capabilities, affordability, etc., prior to proceeding with more in-depth investigations and selection of the supplier and of the offered system. Indeed, such tests may provide valuable knowledge to rule out particular suppliers/solutions, or on the other hand to decide to narrow the choice to some other ones, but can rarely lead to a final decision.

After this first step, ending with a first classification of the applicants/offers, the request for a second offer can be made, involving the definition of the target and fully developed systems, with all required features, capabilities, customizations and, of course, the detailed and final economic offer. This request can in principle result in relevant cuts of systems’ costs, as the applicants will have a better view of the tender and will be stimulated to reduce the economic offer in order to increase their competitive appeal. This could be economically effective for the Public Administration, but it could affect the negotiation phase and the management of the effective implementation of the system .

After completion of this second phase, the contract negotiation phase can be started with the applicant that was awarded the highest score (highest combined technical and economic evaluation). During the negotiation, the technical congruity of the proposal will be evaluated in depth, in terms of human resources, timing of implementation,

customization and testing of the functionalities required in the Technical Annex, as well as on the basis of previous implementation experiences reported by the applicant.

Generally, the purchaser shall anyway take all formal (and legal) measures to keep the right not to conclude the tender process and to declare the tender not awarded successfully to any applicant.

7.3.4 Modification of the economic value of the tender

The administrative documentation of the tender should include an article enabling the customer to modify, up to a certain limit, the economic value of the tender after the selection of the offer. Generally, when applicable, this will be subject to specific national regulations and legal requirements. In Italy, for instance, this limit can be up to 20% of the cost stated in the tender.

Such a provision will increase the flexibility of the purchaser in case of system modifications (e.g. number of components/devices, etc.) that might be eventually identified as necessary after the evaluation and selection process. This may arise, for instance, during negotiation, contract definition or even system implementation.

7.3.5 Definition of the Implementation Plan, milestones and payments

The documentation of the tender shall include a timetable of all activities related to the implementation, integration, testing and start up of the system. The timetable shall be generally described in terms of:

- scheduling of the different phases of implementation, with definition of the timing foreseen for the finalization of each phase;
- each implementation phase will represent a sort of “prototype system” of reduced size (e.g., for AVM systems, the system shall be implemented on all vehicles operating from a specific depot) but ensuring all the functionalities required by the final system;
- each implementation phase will end with a milestone (e.g., again for AVM systems, the start up of a prototype system comprised of: the Control Centre, the communications infrastructure at the depot and the on-board devices installed on the vehicles operating from the depot); and
- definition of the macro-activities involved for each implementation phase (e.g., for AVM systems: installation, integration and start up of the Control Centre; installation, integration and start up of on-board devices, etc.).

The payments shall be generally divided in two main categories: intermediate payments and final payment.

The intermediate payments will relate to the milestones of the implementation phases, as defined in the plan. Intermediate payments will be established in order to provide the supplier with the suitable cash flow related to the implementation and achievements of the step until the relevant milestones; the payments will be released only after the

successful acceptance of the relevant “prototype system” through a testing period of suitable duration.

The proper amount of the intermediate payments will result from the balance between two contrasting factors: the need of the purchaser to reserve enough money for the final payment (i.e. as the main economic leverage to control the supply) and the need to ensure the supplier the necessary cash flow for the effective implementation and start up of the system in all its components. The final payment will be carried out after the successful testing and acceptance of the complete system.

7.3.6 Start and completion of installation activities

In case the implementation of the tendered system will involve any installation activity (e.g. on-board devices to be installed on the vehicles, for the AVM system) the administrative documentation of the tender shall include specific provisions related to the operation of starting and closing the installation.

Taking the case of AVM systems as an example, the start of installation activities shall include the release to the supplier of the vehicles, recovery areas (for logistics and materials) and locations where the installation will be performed. This operation shall be formally stated through the signing of a document (e.g. a Start of Installation form) where the status of each supplied good and resource is reported and the supplier acknowledges the effectiveness of the released goods.

At the end of installation activities, when the supplier will release the vehicles (equipped with on-board devices), the recovery areas and the locations where the installation was performed, the current status of the concerned materials and resources shall be verified and reported in the relevant forms. Such forms shall be signed jointly by the representatives of the supplier and the purchaser, and shall include a statement certifying the successful completion of all planned system installation activities as well as the safe release of the purchaser materials and resources.

7.3.7 System testing procedure

The procedure defined for system testing involves two main test phases and types: the intermediate tests related to the “prototype system” planned for release during system implementation, and the final tests, related to the testing of the final complete system.

A successful intermediate testing will result in the acceptance of the “prototype system” by the customer, the release of the related payment to the supplier as well as the start of the operational use of the prototype system by the customer. The administrative documentation of the tender shall explicitly indicate that the success of the intermediate test does not imply the acceptance of the “prototype system”, as the acceptance proper is related to the successful final test of the complete system.

The success of the final testing of the complete system will mean the acceptance of the system by the customer. The payment of the related (and last) amount reported in 291

the payment plan will thus be performed and the start of the maintenance period will be registered.

Each testing phase (both intermediate and final) will be organized into three different levels:

- quantitative and technical congruence of implementation activities;
- functional test; and
- performances test.

The first level of testing shall involve the verification that the appropriate numbers of components/devices have been installed, the results and effectiveness of installation activities, etc. The second level of testing shall mainly involve the verification of the general compliance of system functionalities with respect to the requirements stated in the documentation of the tender (Technical Annex of the contract). The tests must be performed as regards both each component/device and the entire system. The third level of testing shall involve the verification of the compliance of system functionalities with respect to the requirements stated in the documentation of the tender over a specified period of time. This level of testing will involve comparing the measured performance of the system – as described by the adopted performance indicators measured at the end of each phase or at the end of the overall implementation plan – against the “target values” specified in the Technical Annex.

7.3.8 Termination of implementation: penalties and options

The tender documentation should describe the penalties and quantify their amounts in relation to the unsuccessful termination of system implementation activities generally, the penalties shall refer to:

- delays in the time required to complete successfully the acceptance of each implementation phase, compared to the schedule of the Implementation Plan described in the tender documentation;
- delays in the time required to complete successfully the acceptance of the overall system, compared to the schedule of the Implementation Plan described in the tender documentation;
- delays and/or insufficient or lack of compliance of maintenance interventions, compared to the Service Level Agreement defined in the tender documentation; and
- insufficient or lack of compliance of the measured performances (performance indicators) in the maintenance of the system, compared to the SLA defined in the tender documentation.

The tender documentation shall include specific provisions giving full description and account of the reasons for contract termination by customer. Beside the standard legal reasons defined by the governing law of the contract, some additional technical motivations shall be added, like for instance:

- delays in the time required to complete successfully the acceptance of each implementation phase, exceeding a maximum delay stated in the administrative documentation;
- delays in the time required to complete successfully the acceptance of the overall system, exceeding a maximum delay stated in the administrative documentation;
- failed acceptance of the detailed technical and functional specifications of the system (first intermediate phase of the implementation plan);
- failed acceptance of an intermediate phase of the implementation plan (intermediate testing phase not accepted successfully);
- failed acceptance of the completed system (failed final testing); and
- total amount of penalties (calculated as previously explained) exceeding a defined percentage of the total cost of the tender.

7.4 The evaluation of tenders: an introduction

G. Ambrosino

In the context of the ITS procurement process, it is important to follow a sound methodology for reading and analysing the different bids and, at the same time, to support the related evaluation and classification of the bidders. The main operational objective is to provide the Evaluation Committee members with a useful tool (methodology) to:

- structure and manage the reading and analysis of each offer, which is very often a difficult task due to the quantity of proposals to be assessed and sometimes due to the lack of clarity of the bid documentation;
- summarize the characteristics and the main components of each bid/tender;
- classify and evaluate each bid in an impartial and transparent manner; and
- establish a decision process based on analytical, operational and clear criteria in order to let the bidders understand the evaluation process followed by the Contracting Authority.

The methodology drafted in this section has been applied and tested in different procurement processes at the European and international level, addressing different advanced ITS systems (Urban Traffic Control, UTC; Automatic Vehicle Monitoring, AVM; Variable Message Signs, VMS; Access Control, AC; Integrated Payment Systems, IPS; etc.), examples of which have been considered in Chapters 3 and 4.

This section provides a general structure – a sort of backbone – for an evaluation methodology, which should be customised to the different requirements of the specific Call for Tender defined by the Contracting Authority. To better understand its main features, the evaluation methodology is described taking as an example a real application in the context of an international Call for Tender where an ICT management service

for the Metro-Q transport system of Quito (Ecuador) was to be acquired (see section 3.10). In particular, the Call for Tender, addressing the Bus Rapid Transit (BRT) central corridor “TROLEBUS” in Quito, required the implementation of a set of systems (AVM, Integrated Payment System, User Information, TVCC, long and short range communication network, etc.) and their operation and maintenance for 9 years.

Figure 7.2 provides an overview of the general structure of the evaluation process and the background of the detailed methodology described in the remainder of this section.

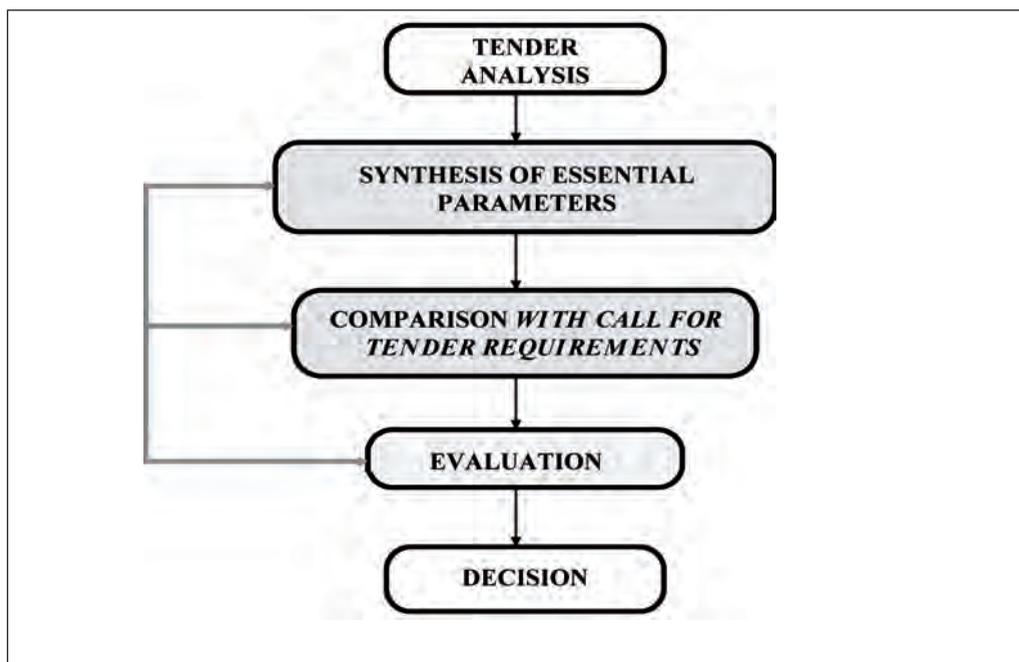


Figure 7.2: Overall structure of the evaluation process

7.4.1 Guidelines for a general methodology

The key of the methodology is the definition of an appropriate set of detailed evaluation criteria based on the decomposition of the evaluation criteria defined in the Call for Tender documentation and on the modality required to the tenderers for describing their offer. Looking at the case taken as a background example – the procurement of the AVM and IPS system for the Public Transport corridor (TROLE) of Quito – the following evaluation criteria and parameters were defined in the Call for Tender:

- a) technical characteristics of the systems,
- b) experiences and background of the tenders,
- c) cost of the services as per cent of operation revenue,

- d) timing of installation, operation and service concession,
- e) financial capacity of the tenders/bidders.

Based on this set of criteria, a suitable selection of more detailed evaluation parameters can be defined. For example, the first criterion/parameter, a) “technical characteristics of the systems” (related to the technological/technical aspects of the tendered systems) has been decomposed into several sub-components (technological and not) and related main characteristics, which have been given a specific “weight” stating the relevance of the parameter within the overall evaluation scheme.

Generally, whenever the Call for Tender documentation includes the guidelines “*how to describe the offer*” (as an Annex) this will be the starting point for the decomposition and further definition of the different evaluation criteria and parameters. Each evaluation criteria/parameter established in the Call for Tender, shall be further decomposed into sub-parameters (evaluation levels) and for each of them the main characteristics/components to be analysed during the reading of the tender by the Evaluation Committee Members (ECMs) shall be defined. Furthermore, a “*weight*” shall be associated to each identified sub-parameter as an indicator of the relevance of the specific sub-parameter in the context of the entire set of sub-parameters of the same level.

This decomposition process of each criterion should continue until the appropriate level will be achieved in order to assist the ECMs in their evaluation task. In any case, ECMs should be given the opportunity (and method) to modify and/or add new elements on the basis of their experiences or of specific bid requirements.

At the end of this iterative decomposition process, a quite extensive “*hierarchical table*” will have been obtained, where the row of each level represents a sub parameter/characteristic/component with a specific weight in the context of the same level. This is the reference “*Evaluation Table*” to be used by each ECM during the reading and analysis of each offer, taking note of specific comments for each row (element/sub-parameter) and assigning the related “*mark*” to the corresponding weighted characteristics/sub parameter.

At this stage, it is important to anticipate two aspects that will be clarified further in the remainder of this chapter:

- the “*marks*” to each sub-component should be only given after the “*weight*” of each sub-parameter/component has been established, element by element (row by row) and level by level;
- each tender should be read and analysed taking into account the objectives and indications described in the “Call for Tender” process documentation. The tenders should not be evaluated by direct cross-comparison of their constitutive elements: each tender should be individually and fully assessed against the requirements described in the Call for Tender documentation, a cross-comparison being naturally generated as the last step of the structured evaluation methodology itself.

7.4.2 Main phases of the evaluation methodology

The methodology supporting the tenders evaluation process involves the following main phases:

- F.1 Defining the “Evaluation Table”:** identification of the suitable characteristics/components for each “level” of evaluation criteria established in the Call for Tender (in our example, the criteria a).....e) introduced above).
- F.2 Defining the “Weighted Evaluation Table”:** identification of the appropriate “weight” (i.e. importance) for each sub-parameter/component of the same level.
- F.3 Assessment of individual characteristics/components:** reading, analysis and rating of the tender, with production of a description synthesis for each component of the same level, assignment of a “mark” (rating) to each characteristic/component in a bottom-up process, starting from the lowest levels of the “Weight Evaluation Table” and/or final sub-parameters.
- F.4 Overall assessment: cross-comparison of the offers:** assignment of the final mark to each criterion of the Call for Tender, as a result of the weighted marking of the lower levels of the table.

To clarify this approach, in the remainder of this section we provide an idea of the activities carried out in each phase, again following, as an example, the evaluation process adopted in the Quito Call for Tender.

F1. “Evaluation Table”

In this phase, the Evaluation Table is set up. This phase defines the whole set of sub-parameters/components of each evaluation criteria (the criteria from a) to e) of our example) taking into account the requirements and technical aspects pointed out or described in the Call for Tender documentation. The higher level (level 0) of this decomposition process is thus given by the 5 evaluation criteria identified in the Call for Tender, as shown in Table 7.3.

Level 0	Call for Tender Criteria/Parameters
a.	technical characteristics of the systems,
b.	experience and background of the tenders,
c.	cost of the services as per cent of operation revenue,
d.	timing of installation, operation and service concession
e.	financial capacity of the tenders/bidders.

296 Table 7.3: Evaluation Table – Level 0

Each of the above parameters (criteria) has then been decomposed until a detailed level that was considered by the EC members sufficient for a suitable and exhaustive analysis and evaluation. For example, criterion a) “technical characteristics of the systems” has been decomposed into six different sub-parameters/components as shown in Table 7.4, taking into account also the different targeted systems of the Call for Tender.

Parameter a. Level 1	technical characteristics of the systems
a.1	General Design
a.2	Integrated Payment System
a.3	Automatic Vehicle Monitoring (+ user information and TVCC systems)
a.4	Large Communication Network
a.5	Integration Levels among the different systems
a.6	Quality of installations at board and road levels

Table 7.4: Evaluation Table – Level 1

Continuing in the hierarchical decomposition process of the evaluation components, all relevant components of this level have been further broken down into other sub-components/parameters. Still following the example of Quito, the sub-component a.3) Automatic Vehicle Monitoring (+ User Information and TVCC system) has been decomposed into several other sub-components/parameters as shown in table 7.5.

Sub-Parameter a.3 Level 2	Automatic Vehicle Monitoring (+ User Information and TVCC system)
a.3.1	Control Room of AVM system
a.3.2	Service planning s/w
a.3.3	On-board equipment
a.3.4	User information system at terminal, stop and road
a.3.5	TVCC system

Table 7.5: Evaluation Table – Level 2

At this stage, some of these sub-components have been further split into lower level evaluation elements. For example, the sub-component a.3.3) was decomposed as shown in the Table 7.6.

Sub-Parameter a.3.3. Level 3	On board equipment
a.3.3.1	Technical characteristics of the devices for the data/voice communication
a.3.3.2	Technical Characteristics of the location device
a.3.3.3	Technical Characteristics of passenger counter
a.3.3.4	Technical Characteristics driver Terminal
a.3.3.5	Characteristics technical of the control unit
a.3.3.6	Characteristics of on-board information devices
a.3.3.7	Functionalities of driver terminal
a.3.3.8	Functionalities of control unit
a.3.3.9	Functionalities of on board user information

Table 7.6: Evaluation Table – Level 3

Once this top-down structuring of evaluation criteria is completed – i.e. once the level of detailed description of each characteristic/component is judged as clear, unambiguous and satisfactory for the purpose of the evaluation of the tendered system – the lowest level structured tables can be used as guidelines for driving the reading and analysis of the specific sub component (in our example, the on-board equipment).

From these tables (indicated as final evaluation criteria break down tables) the analysis of the technical offer can start. Looking at the generic evaluation table, some sub-parameters could be considered as “final” parameters (final row) and presented in a table whereas other sub-components/parameters could be still decomposed in to other sub-parameters (for example in Table 7.6 the sub-parameters a.3.3.7, a.3.3.8 and a.3.3.9 have been further decomposed) leading to other sub-level tables. This process shall be repeated for every evaluation criteria and every identified sub- component/ parameter.

F2. “Weighted Evaluation Table”

The main activity of this phase is the assignment of a “weight” (level of relevance) to each component/sub-parameter within each table (level) identified in the previous phase F1. In practice, a weight shall be assigned to each row of the same table/level. That is, a specific weight is given to each component of the same table/level in order that the total sum of the weights of all components (all rows) of the table is equal to 100 (this to better understand the importance of the different components of the same level).

In most cases, the weights of the first level (level 0) will be already available from the definition provided in the documentation of the Call for Tender. For instance, in the case of the Quito Call for Tender, the weights of the first level decomposition of evaluation criteria were defined, in the accompanying documentation, as shown in Table 7.7.

Level 0	Base Criteria/Parameter	Weight
a.	technical characteristics of the systems,	25
b.	experiences and background of the tenders,	15
c.	cost of the services as per cent of operation revenue,	35
d.	timing of installation, operation and service concession	15
e.	financial capacity of the tenders.	10
	Total	100

Table 7.7: Weighted Evaluation Table – Level 0

In the next level, for each identified sub-components this process of weight assignment is repeated. For example, for the lower levels of criterion a) (Table 7.4) the identified weights are shown in Table 7.8.

Parameter a. Level 1	technical characteristics of the systems	Weight
a.1	General Design	5
a.2	Integrated Payment System	40
a.3	Automatic Vehicle Monitoring (+ user information and TVCC systems)	25
a.4	Large Communication Network	15
a.5	Integration Levels among the different systems	10
a.6	Quality of installations at board and road levels	5
	Total	100

Table 7.8: Weighted Evaluation Table – Level 1

This process is to be repeated for all the identified tables. For instance, with the assignment of specific weights to each components, Table 7.5 is transformed in Table 7.9 below.

Sub-Parameter a.3 Level 2	Automatic Vehicle Monitoring (+User Information and TVCC system)	Weight
a.3.1	Control Room of AVM system	30
a.3.2	Service planning s/w	15
a.3.3	On-board equipment	25
a.3.4	User information system at terminal, stop and road	20
a.3.5	TVCC system	10
	Total	100

Table 7.9: Weighted Evaluation Table – Level 2

With the assignment of a weight to each component of each level, the overall evaluation table is completely defined. This will be used as a supporting tool during the evaluation of each received tender: an instance of the defined set of tables will be generated for each offer to the tender, filling in the tables by scoring each component/characteristic as described for phase F3 in the next section.

F3. “Assessment of individual characteristics/components”

This phase is related to the reading process proper of each offer, and to the analysis of the offer and the scoring of (i.e. assignment of marks to) each component of each level, starting from the components defined at the lowest level (final tables).

In this phase it will be necessary to:

- describe and comment on the characteristics of the offered components; i.e. fill in the columns “offer” and “note” of the tables (see Table 7.10);
- give a mark to each component (each row) starting from the lowest levels (final table) or final sub-parameters.

Once the final table/level has been filled in completely and the marks have been given to all final sub-parameters (which can be included in a non-final table) the marks of the components of the upper levels are automatically calculated taking into account the different weights and the related lower marks.

For instance, assuming that Table 7.9 is the “final” level/table, Table 7.9 could be

Sub-Parameter a.3 Level 2	Automatic Vehicle Monitoring (+ User Information and TVCC system)	Offer	Note	Mark	Weight
a.3.1	Control Room of AVM system			$V_{A.3.1}$	$P_{A.3.1}$
a.3.2	Service planning sw			$V_{A.3.2}$	$P_{A.3.2}$
a.3.3	On board equipment			$V_{A.3.3}$	$P_{A.3.3}$
a.3.4	User information system at terminal, stop and road			$V_{A.3.4}$	$P_{A.3.4}$
a.3.5	TVCC system				
TOTAL a.3				$V_{A.3.}$	100

Table 7.10: Sample assessment of individual component/characteristic

In the column “offer”, the EC members summarize what the bidders have described for that specific component/sub-parameter, while in the column “note” the related comments of the ECMs might be included, if appropriate. In the column “mark”, the EC members shall enter their own evaluation (mark) related to the specific component (for better understanding, ranging from 0 to 100).

The final mark of this component $V_{A.3.}$ is automatically transferred to the upper level, as the overall mark of the component/sub-parameter a.3) Automatic Vehicle Monitoring (+ User Information and TVCC systems) defined in the table describing the criterion a) “*technical characteristics of the systems*”, as shown in Table 7.11.

The overall evaluation of the criterion – V_a – is computed as a “weighted sum” (as it is also made for the overall evaluation of the sub-parameter $V_{a.3}$) of each mark obtained by each sub-parameter/component.

Parameter a. Level 1	Technical characteristics of the systems	Mark	Weight
a.1	General Design		
a.2	Integrated Payment System		
a.3	Automatic Vehicle Monitoring (+ User Information and TVCC system)	$V_{a.3}$	$P_{a.3}$
a.4	Large Communication Network		
a.5	Integration Levels among the different systems		
a.6	Quality of installations at board and road levels		
TOTAL a.		V_a	100

Table 7.11: Technical characteristics of the system

F4. “Overall assessment: cross-comparison of the tenders”

In this phase, the comparison of the marks obtained by each offer is provided as shown in Table 7.12, where all the marks computed at the top level (level 0) for each offer is represented by a specific column. In practice, this results in a summary table having as many columns as the number of offers – plus the common general “weight” column – and as many rows as the adopted top level (level 0) evaluation criteria/components/ characteristics.

Level 0	Base Criteria	Mark Bidder 1	Mark Bidder 2	Mark Bidder M	Weight
a.	technical characteristics of the systems	V_A^1	V_A^2		V_A^M	P_A
b.	experiences and background of the tenders	V_B^1	V_B^2	...	V_B^M	P_B
c.	cost of the services as per cent of operation revenue	V_C^1	V_C^2	...	V_C^M	P_C
d.	timing of installation, operation and service concession	V_d^1	V_d^2	...	V_d^M	P_d
e.	financial capacity of the tenderer	V_e^1	V_e^2	...	V_e^M	P_e
	TOTAL	V_0^1	V_0^2	...	V_0^M	100

Table 7.12: Overall assessment: cross-comparison of tenders

This way, the EC members can achieve an easy comparison of the marks of each tender, both as regards the evaluation criteria (five in the case of Quito Call for Tender) and also for all the sub-parameters/components into which these criteria have been decomposed.

7.4.3 The methodology as a “tool” for the Evaluation Committee Members

From a functional and operational point of view, the methodology outlined in previous chapters can be considered as a support tool for the EC member during the evaluation of the received tenders. The tool will provide support, in general, for a number of activities including:

- before the reading and the evaluation of the different tenders, to specify and personalise the most relevant elements for summarising and describing the tender, starting from the overall requirements of the Call for Tender documentation and the additional indications of the EC members;
- to identify the sub-parameters/components related to each evaluation criteria (as defined in the Call for Tender documentation);
- to collect and organise the main information/descriptions provided by each tender following a common layout;

- to assess in an homogenous way the information/data of the tender comparing them with the related requirements described in the documentation of the Call for Tender;
- to assign objective marks to each component and criterion of each tender;
- to include judgements and assessments about each individual component, and considering these for the overall evaluation of each tender;
- to cross-compare the evaluation of each tender in a synthetic, easy and immediate way.

Operationally, this methodology can be implemented by using common tools (e.g. commonly used spreadsheets like MS Excel™) resulting in easy to use and flexible evaluation systems that allow almost any kind of personalisation, as it may be required by the members of the Evaluation Committee.

The methodology has been applied and personalised to the requirements and criteria defined in the documentation of different Call for Tenders – among which the one of Quito, illustrated in this section. Actually, for the evaluation of the Quito tenders, a single spreadsheet (Excel) comprised of two main parts was realised:

- *i*) a first part was used for the reading, analysis and scoring of the different components/sub-parameters of each tender, producing one large “*Evaluation Table*” for each tender;
- *ii*) a second part was defined as a comparative table across the different tenders, providing a summary of the overall marks obtained for each component (row) of each table related to each tender, resulting from the above step *i*).

Section 7.3 provided some guidelines for defining the supporting documentation for a Call for Tender aimed at the purchasing of an advanced ICT system (actually, the case of an AVM system, which can also be used as a base scheme for contracting other types of ITS systems). The methodology illustrated in this section should be regarded as a “companion tool” closely related to the guidelines described in Section 7.3, to be taken into consideration when defining the documentation of the Call for Tender particularly for the description of the proposals (tenders) and the choice of specific evaluation criteria and tables.

Bibliography

- AA.VV., *“Progetto di integrazione e sviluppo tecnologico dei sistemi di controllo della mobilità nell’area vasta di Cagliari”*, Internal report, 2001
- AA.VV., *Public Transportation Fact Book. 53th edition*, American Public Transportation Association, Washington, DC, 2002a
- AA.VV., *Freight Analysis Framework*, Federal Highway Administration, 2002b
- AA.VV., *Amici della Terra, Valutazione del vantaggio, in termini di minori costi ambientali e sociali di un forte sviluppo del trasporto collettivo in ambito urbano*, Enea, 2003
- AA.VV., *“Metropolitana dell’area vasta di Cagliari: studio di fattibilità – progetto preliminare”*, Internal report, CTM s.p.a., 2004
- AA.VV., *“Prime considerazioni sulla rilevazione delle informazioni presso le Aziende di Trasporto Pubblico Locale”*, IMoSPro project, Rapporto interno Consorzio Technomobility, 2005a
- AA.VV., *“Technical and organizational analysis for Mobility services”*, IMoSPro project, Rapporto interno Consorzio Technomobility, 2005b
- AA.VV., *“Economic Analysis”*, IMoSPro project, Internal report Consorzio Technomobility, 2005c
- AA.VV., *“Manuale d’uso del PDA”*, IMoSPro project, Internal report Consorzio Technomobility, 2005d
- AA.VV., *“Manuale d’uso del monitoraggio sinottico di linea”*, IMoSPro project, Internal report Consorzio Technomobility, 2006
- AMBROSINO G., SASSOLI P., ZATTERONI B., *Guida ai sistemi di telecontrollo delle flotte del trasporto collettivo*, Consiglio Nazionale delle Ricerche, progetto finalizzato trasporti 2, 1996

- AMBROSINO G., MAGEEAN J.F., NELSON J.D. AND ROMANAZZO M., *Experience and applications of DRT in Europe*. In Ambrosino G., Nelson J.D. and Romanazzo M. (Eds), *Demand Responsive Transport Services: Towards the Flexible Mobility Agency*, pp.141-197, Rome, ENEA, 2004
- AMBROSINO G., BOERO M., LIBERATO A., *eDRUL City eLogistics Agency*, Genesi gruppo editoriale, 2005
- AMBROSINO G., BOERO M., NELSON J.D. AND ROMANAZZO M. (Eds), *Systems and Advanced Solutions for e-Logistics in the Sustainable City*, Rome, ENEA, 2005
- AMBROSINO G. ET AL., *The Agency for Flexible Mobility Services on the move*, booklet IST Programme, January 2005
- AMBROSINO G., NELSON J.D., ROMANAZZO M., *Updated Version of "Demand Responsive Transport Services: Towards the Flexible Mobility Agency"*, eds MemEx, Livorno, February 2009 CD version, 2009
- BARABINO B., *Il progetto IMoSPro, Intelligent Mobility Service Provider: esperienza nell'area vasta di Cagliari*, Paper presented at "I servizi flessibili e l'infomobilità per il TPL nell'area vasta di Cagliari", April 2006
- BARABINO B. (edited by), *Agenzia integrata per il governo del trasporto pubblico locale: progetto europeo AGATA*, Franco Angeli (on printing), 2007
- BARCELO J., BARCELO P., CASAS J., FERRER J.L., "AIMSUN: New ITS Capabilities", Proceedings European ITS Conference, Bilbao, 2001
- BARCELÓ J., CASAS J., FERRER J. AND PERARNAU J., *A Simulation Study to Evaluate the Performance of Adaptive Control Strategies for Traffic Safety Conditions in the Vielha Tunnel*, Paper #3759, 82nd TRB Meeting, Washington, 2003
- BERTAZIOLI O., FAVALLI L., *Gsm-Gprs*, Hoepli, 2002
- BHOURI N., HAJ-SALEM H., *La fiabilité des réseaux de transport de surface: exemple d'application en contrôle d'accès*, Congrès ATEC-ITS FRANCE, 4-5 février Versailles, 2009
- BRAKE J.F. AND NELSON J.D., *A case study of flexible solutions to transport demand in a deregulated environment*, Journal of Transport Geography, 15(4), pp.262-273, 2007
- BRAKE J.F., MULLEY C. AND NELSON J.D., *Good Practice Guide for Demand Responsive Transport Services using Telematics*, Newcastle upon Tyne, University of Newcastle upon Tyne, 2006
- BRAKE, J., NELSON, J. AND WRIGHT, S., *Demand responsive transport: towards the emergence of a new market segment*, Journal of Transport Geography, 12(4), 323-337, 2004
- CASEY R.F., LABELL L.N., PRENSKY S.P., SCHWEIGER C.L., *Advanced Public Transportation Systems: The State of the Art Update '98*, Federal Transit Administration, Washington D.C., 1998
- CAULFIELD B., O'MAHONY M., *An examination of the public transport information requirements of users. IEEE Transactions on Intelligent Transportation Systems*, vol. 8, pp. 21-30, 2007
- CERTU, *Évaluation des transports en commun en site propre. Indicateurs transport pour l'analyse et le suivi des opérations*, 1997

- CERTU, *Bus with a High Level of Service. Concept and recommendations*, 2005
- COOPER J., NELSON J.D. AND WRIGHT S., *The delivery of Rural Flexible Transport: Experiences from Highland Scotland*, In Traffic and Transportation Studies, ICTTS 2006 Mao, Tian, Gao and Huang (Eds), pp 156-166, 2006
- CORONA G., TILOCCA P., BARABINO B. ET AL., “MAVC: Una metropolitana automatizzata per l'area vasta di Cagliari”, La valutazione come riferimento per la pianificazione: Cagliari e il suo contesto, XXXIII Incontro di Studio-Cagliari 2003, 2003
- CORONA G., TILOCCA P., ANGIUS S., FARRIS S., “Progetto di integrazione e sviluppo tecnologico dei sistemi di controllo della mobilità nell'area vasta di Cagliari”, La valutazione come riferimento per la pianificazione: Cagliari e il suo contesto, XXXIII Incontro di Studio - Cagliari 2003, 2003
- CRAINIC T.G., “Planning Processes and Operating Strategies in the E-Age”, Seminario, Cagliari, 2006
- CRISTIANINI N., SHAWE-TAYLOR J., “An Introduction to Support Vector Machines”, Cambridge University Press, 2000
- CTM S.p.A., *Carta della mobilità*, 2005
- DEMERY D., GILCHRIST P., GUENTHER B. AND MULDER E., *Philips J. Res.* 48, 1994.
- DOMENICHINI L., DI VOLO N., SERVENTI R., “Microsimulation Model for the New Italian Motorway System A1 – A1bis from Bologna to Firenze”, Proc. ASECAP Portoroz International Workshop, 2003
- DOMENICHINI L., DI VOLO N., GIACCHERINI A., BARCELO J., FERRER J.L., *Microsimulation Techniques for the Analysis of Safety Management in Tunnels*, ITS Safety and Security Conference, Miami, USA , FL., 2004
- DOMENICHINI L., DI VOLO N., GIACCHERINI A., “Identification of Safety Indicators for Road Traffic Management in Tunnels Using Microsimulation Techniques”, Proc. II International SIIV Congress, Firenze, 2004
- eMOTION, www.emotion-project.eu, 2006
- eMOTION, eMOTION Deliverable D5, *eMOTION Systems: Analysis of Technical Standards*, R.Erstling, Olk S. et al., 2007
- eMOTION, eMOTION Deliverable D8, *Recommendations on eMOTION service framework conditions*, Boero M., Masnata M. et al., 2008
- EUROPEAN COMMISSION, *Green Paper - Towards a European strategy for the security of energy supply* Office for official publications of the european communities, 2000
- EUROPEAN COMMISSION, *European Transport Policy for 2010: time to decide*. Luxembourg: EC. http://www.europa.eu.int/comm/transport/white_paper/index_en.htm, 2001
- EUROPEAN COMMISSION, *Keep Europe moving - sustainable mobility for our continent*, Luxembourg: EC. http://ec.europa.eu/transport/strategies/2006_keep_europe_moving_en.htm, 2006

- EUROPEAN COMMISSION INTELLIGENT TRANSPORT SYSTEM (EC-ITS), ITS Roadmap Outline “*Intelligent Transport Systems (ITS) for more efficient, safer and cleaner road transport*”, Road: Public consultations. Preparation of the Action Plan on Intelligent Transport Systems (ITS) for Road Transport. http://ec.europa.eu/transport/road/consultations/doc/2008_03_26_its_road-map_outline.pdf, 2007
- EUROPEAN COMMISSION, Green paper “*Towards a new culture for urban Mobility*” COM 551) http://ec.europa.eu/transport/clean/green_paper_urban_transport/, 2007
- EUROPEAN COMMISSION, *Action Plan for the Deployment of Intelligent Transport Systems in Europe* [COM(2008)886], <http://ec.europa.eu/transport/its/>, 2008
- EU - COMMISSION OF THE EUROPEAN COMMUNITIES, *Commission Staff Working Document. SEC 3083*, Available online at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:3083:FIN:EN:PDF>, 2008
- FIELDING G.J., BABITSKY T.T., BRENNER M.E., *Performance Evaluation for bus transit. Transport Research-A*, Vol. 19A, n. 1, pp.73-82, 1985
- FINN B., FERRARI A. AND SASSOLI P., *Goals, requirements and needs of users*. In Ambrosino G., Nelson J.D. and Romanazzo M. (Eds) *Demand Responsive Transport Services: Towards the Flexible Mobility Agency*, pp. 33-54, Rome, ENEA, 2004
- FRANZ D.W., “*Car-to-car Communication – Anwendungen und aktuelle Forschungsprogramme in Europa, USA und Japan*”, in Kongressband zum VDE-Kongress 2004 - Innovationen für Menschen, VDE, October 2004
- FROSINI P., HUNTINGFORD J., AMBROSINO G., “*Multi-services agency for the integrated management of mobility and of accessibility to transport services*”, *European Transport*, vol. n. 28 pp. 34-43, 2004
- GARIB A., RADWAN A.E., AND AL-DEEK H., “*Estimating Magnitude and Duration of Incident Delays*”, *Journal of Transportation Engineering*, Vol. 123, No. 6, pp. 459-466, 1997
- GATTUSO D., *Per un'analisi delle prestazioni dei sistemi di trasporto a guida automatica in area urbana*, Quaderno di Istituto n.3/92, Università di Reggio Calabria, 1992
- GATTUSO D., MEDURI G., GALLETTA A., ROMEO A., *Indicatori per la valutazione della gestione di sistemi di trasporto pubblico. Applicazione su contesti urbani*, p.18, 2002
- GILLEN D., LI J., DAHLGREN J., CHANG E., *Assessing the Benefits and Costs of ITS Projects: Volume 1 Methodology*, California PATH, University of California, Institute of Transportation Studies, Berkeley, CA, 1999
- GIULIANO G., “*Incident Characteristics, Frequency, and Duration on a High Volume Urban Freeway*”, *Transportation Research*, Vol. 23A, No. 5, pp. 387-396, 1989
- GOLOB T.F., RECKER LEONARD J.D., “*An Analysis of the Severity and Incident Duration of Truck-Involved Freeway Accidents*”, Institute of Transportation Studies, Univ. of California, Irvine, UCI-ITS-WP-86-9, 1986

- GROTENHUIS J.W., WIEGMANS B.W., RIETVELD P., *The desired quality of integrated multimodal travel information in public transport: Customer needs for time and effort savings*, Transport Policy 14, pp. 27-38, 2007
- GUDMUNDSSON H., HÖJER M., "Principles of sustainable development and their implications for transport", Journal of Ecological Economics, vol.19 n.3, pp. 269-282, 1996
- GUNN S.R., *Support Vector Machines for Classification and Regression*, Technical Report, Image Speech and Intelligent Systems Research Group, University of Southampton, (<http://www.isis.ecs.soton.ac.uk/isystems/kernel/>), 1997
- GUPTA P. AND KUMAR P.R., "The capacity of wireless networks", IEEE Transactions on Information Theory, vol. 46, no. 2, pp. 388-404, March 2000
- GUPTA A., MASLANKA V., SPRING G., *Development of a Prototype KBES in the Management of Congestion*, Transportation Research Board, Washington D.C., 1992
- HALDEN D., *Report to the Scottish Executive on the delivery of Demand Responsive Pilot Schemes in Scotland*, (Derek Halden Consulting), Scottish Executive report, 2005
- HALDEN ET AL, *Review of Demand Responsive Transport in Scotland conducted for the Scottish Executive by Derek Halden Consultancy, the TAS Partnership and the University of Aberdeen*, 2006 (<http://www.scottishexecutive.gov.uk/Publications/2006/05/18112606/0>)
- HINE J., SCOTT J., *Seamless, accessible travel: user's views of the public transport and interchange*, Transport Policy 7, pp. 217-226, 2000
- HÖEJER M., "Urban transport, information technology and sustainable development", World Transport Policy and Practice 2/1,2, pp. 46-51, 1996
- HÖEJER M., "Transport telematics in urban system - A Backcasting Delphi study", Transportation Research D, vol.3 n.6, pp. 445-463, 1998
- HUBAUX J.P. ET AL., "The security and privacy of smart vehicles", IEEE Security & Privacy, vol. 4, no. 3, pp. 49-55, May/June 2004.
- ISO 19133, "ISO 19133:2005 Geographic information - Location-based services - Tracking and navigation", International Organization for Standardization (ISO), 2005.
- ISO 19134, "ISO 19134:2007 Geographic information - Location-based services - Multimodal routing and navigation", International Organization for Standardization (ISO), 2007.
- JONES B., JANSSEN L. AND MANNERING F., "Analysis of the Frequency and Duration of Freeway Accidents in Seattle", Accident Analysis & Prevention, Vol. 23, No. 4, pp 239-255, 1991
- JOURNEYWEB, <http://www.journeyweb.org.uk/>, 2006
- JOURNEYWEB, <http://www.kizoom.com/standards/journeyweb/index.htm>, 2008
- KADY M., RISTENBLATT M., *An Evolutionary IVHS Communication Architecture*, in Vehicle Navigation and Information Systems Conference, Ottawa, Canada, IEEE, October 1993

- KADY M., RISTENBLATT M., *Comparison of Adaptive Medium Access Control Schemes for Beacon-Vehicle Communications*, in Proc. Vehicle Navigation and Information Systems VNIS, pp. 295-299, Ottawa, Canada, IEEE, October 1993
- DER-HORNG LEE, SHIN-TING JENG, *Integrated Freeway Incident Management Using Data Mining and Expert Systems*, Institute of Transportation Studies - University of California – Irvine - USA, 2004
- LIN P.W., ZOU N., AND CHANG G.L., “*Integration of a Discrete Choice Model and a Rule-Based System for Estimation of Incident Duration: a Case Study in Maryland*”, The 83rd Annual meeting of the Transportation Research Board, 2004
- LO H.K., YIP C.W. AND MAK B., *Passenger route guidance system for multi-modal transit networks*, Journal of Advanced Transportation, vol. 39, pp. 271-288, 2005
- LOMAX T., SCHRANK D., TURNER S., MARGIOTTA R., *Selecting travel reliability measures*, Texas Transportation Institute Cambridge systematics, Inc., 2003
- LÜBKE A., “*Car-to-car Communication - Technologische Herausforderungen*”, in Kongressband zum VDE-Kongress 2004 - Innovationen für Menschen, VDE, October 2004
- LYONS G., HARMAN R., *The UK public transport industry of multi-modal traveller information*, Journal of international Transport Management 1, pp. 1-13, 2002
- MACCUBBIN R.P., STAPLES B.L., MERCER M.R., *Intelligent Transportation Systems Benefits and Costs: 2003 Update*, DOT Washington, DC, 2003
- MAC DORMAN L.C., *Public Transport Performance Monitoring*, Transport Research Board, pp. 19-36, 1988
- MESSINA G., MANCINI M., FORMICHI F., *Architettura e funzioni del sistema Mobility*, ENEA - RTI/ERG/SIRE/99/011, Rome - Italy, 1999
- MILLER D.R., LATHROP G.T., STUART D.G., POISTER T.O., *Simplified Guidelines For Evaluating Transit Service*, in Small Urban Areas. Report 8. Transport Research Board, 1984
- MOLIN E., TIMMERMANS H., *Traveler expectations and willingness-to-pay for web-enabled public transport information services*, Transportation Research Part C 14, pp. 57-67, 2006
- MULLEY C. AND NELSON J.D., *Interoperability and transport policy: the impediments to interoperability in the organisation of trans-European transport systems*, Journal of Transport Geography, 7(2), pp. 93-104, 1999
- MULLEY C. AND NELSON J.D., *Flexible Transport Services: a new market opportunity for public transport*, Research in Transportation Economics, 25, pp. 39-45, 2009
- NAM D.H., DREW D.R., *Analyzing Freeway Traffic under Congestion: Traffic Dynamics Approach*, Journal of Transportation Engineering (May/June 1998), pp. 208-212, 1998
- NAM D. AND MANNERING F., *An exploratory hazard-based analysis of highway incident duration Transportation Research Part A: Policy and Practice*, Volume 34, Issue 2, February 2000, Pages 85-102, 2000

- NEUDORFF LO G., JEFFREY P.E., RANDALL E., REISS P.E.R., GORDON R., *Freeway Management and Operations Handbook*, FHWA-OP-04-003, USA, 2003
- NI S.-Y. ET AL., “*The broadcast storm problem in a mobile ad hoc network*”, in Proceedings of the 5th International Conference on Mobile Computing and Networking, 1999.
- NPTG, <http://www.naptan.org.uk>, 2008
- OGC-OPENLS, “*OpenGIS® Location Service (OpenLS) Implementation Specification: Core Services*”, Version 1.1, Open Geospatial Consortium (OGC), 2005-05-02, Ref.No OGC 05-0160, 2005
- OCSE, *Transport public urbain: évaluation des performances*, Recherche Routière, 1980
- K.OZBAY, KACHROO P., *Incident Management in Intelligent Transportation Systems*, Boston: Artech House, 1999
- OZBAY K., PUSHKIN K., *Incident Management in Intelligent Transportation Systems*, MA:Artech House, USA, 1999
- OZBAY K. AND NOYAN N., “*Estimation of incident clearance times using Bayesian Networks approach*” Accident Analysis & Prevention Volume 38, Issue 3, May 2006, Pages 542-555, 2006
- ÖZBAY K., NARAYANAN A., JONNALAGADDA S., *Wide-Area Incident Management Support System*, 3rd Annual World Congress on ITS, Orlando - Florida - USA, 1996
- PENG Z.R., *A methodology for design of GIS-based automatic transit traveler information systems*, Computers Environment and Urban Systems, vol. 21, no. 5, pp. 359-372, 1997
- PENG Z.R., BEIMBORN E., “*A breakeven analysis for statewide ITS project Identification and assessment*”, ITS Project reports, Center for Urban Transportation Studies University of Wisconsin-Milwaukee, October, 2000
- PENG Z.R., HUANG R., *Design and Development of interactive trip planning for web-based transit information systems*, Transportation Research C, vol. 8, pp. 409-425, 2000
- PENG Z.R., BEIMBORN E., NELUHENI M., “*A framework for the evaluation of the benefits of Intelligent transportation systems*”, ITS Project reports, Center for Urban Transportation Studies University of Wisconsin-Milwaukee, November 2000
- RAKHA H., ZHANG W., *Consistency of shock-wave and queuing theory procedures for analysis of roadway bottlenecks*, TRB Paper: 05-1763, Blacksburg - VA - USA, 2001
- RAPP M. AND ALBRECHT C., *Capacity and Slot Management for Heavy Goods Vehicle Traffic Across the Swiss Alps*, Paper #2336, Proceedings of the 10th World Conference on ITS, Madrid, 2003
- REHRL K., BRUNTSCH S. AND MENTZ H.J., *Assisting multimodal travelers: Design and prototypical implementation of a personal travel companion*, IEEE Transactions on Intelligent Transportation Systems, vol. 8, pp. 31-42, 2007
- RITCHIE G.R., PROSSER N.A., *Real-Time Expert System Approach to Freeway Incident Management*, *Transportation Research Record*, n. 1320, 1991

ROKITANSKY C.H., WIETFELD C., *Comparison of Adaptive Medium Access Control Scheme for beacon-Vehicle Communications*, in Proc. Vehicle Navigation and Information Systems VNIS, pp. 295-299, Ottawa, Canada, IEEE, October 1993

RUPERT B., WRIGHT J., PRETORIUS P., COOK G., HUTCHINSON K., KELL W., MACLISTER H., NEVAREZ M., SANDERS L., SCHUMAN R., TAYLOR R., ALMBORG J., *Traveler Information Systems in Europe*, FHWA-PL-03-005 report, 2003

SCHRANK D., LOMAX T., *The 2002 Urban Mobility Report*, Texas Transportation Institute, 2002

SIRI, <http://www.siri.org.uk>, 2008

SMITH B.L., SMITH K., *Forecasting the clearance Time of Freeway Accidents*, Research Report No. UVACTS-15-0-35. USDOT, University Transportation Center, 2001

SMITH K., SMITH B.L., *Forecasting the Clearance Time of Freeway Accidents - Report STL-2001-01*, Center of Transportation Studies - University of Virginia, Virginia - USA, 2001

TEMPO, TEMPO Deliverable D1.4, *Final report on the review of European ITS services*, Broeders et al., 2003

TEMPO, *Traveller Information Services on the Trans-European Road Network: Success stories, current practice and perspectives*, Traveller Information Services (TIS) Expert Group, May 2007

TILOCCA P., BARABINO B., ANGIUS S., *Cagliari: ITS services for mobility management. Preceding of workshops Mobility and Flexible Transport Services: towards the governance and sustainability in European cities*, Florence, 2006

TISA, <http://www.tisa.org>, 2009

TIPPING M., *Sparse Bayesian Learning and the Relevance Vector Machine*, Journal of Machine Learning Research 1, pp. 211-244 (<http://www.miketipping.com/index.php?page=rvm>), 2001

TMC Forum, <http://www.tmcforum.com>, 2003

TRANSXCHANGE, <http://www.transxchange.org.uk>, 2008

TRANSMODEL, <http://www.transmodel.org>, 2001

TRANSPORTATION RESEARCH BOARD, *Highway Capacity Manual*, National Research Council, Washington, D.C., 2000

TRANSPORTATION RESEARCH BOARD, *Strategies for improved Traveler Information*, TCRP Report 92, 2003

TRONCONI O., *Il sistema mobilità: verso una gestione manageriale*, Strumenti di Pianificazione, normativa e tecnologie per il traffic management, ETASLIBRI, 1994

TURNER S., *Travel time reliability measures. NTOC Web Cast: Travel Time Reliability*, June 2006

VALENTI G., MESSINA G., *Metodologia per la progettazione di sistemi di supporto alla pianificazione del traffico urbano*, ENEA - RTI/ERG/SIRE/96/25, Rome - Italy, 1996

- VAN LINT J.W.C., *Freeway Travel Time Reliability Maps; Using the shape of the day-to-day travel time distribution*, Paper presented at the 8th TRAIL congress, Rotterdam, 2004 November 23
- VAPNIK V., “*An Overview of Statistical Learning Theory*”, IEEE Transactions on Neural Networks, Vol. 10, N. 5, pp. 988-999, September 1999
- VINCENT M., *Measurement valuation of public transport reliability*, Land Transport New Zealand Research Report 339, p. 128., 2008
- WANG W., CHEN H., BELL, M.C., “*Vehicle Breakdown Duration Modelling*”, Journal of Transportation and Statistics, 8(1), pp. 75-84, 2005
- WEI CHIEN-HUNG AND LEE YING, *Sequential forecast of incident duration using Artificial Neural Network models*, Accident Analysis & Prevention, Volume 39, Issue 5, September 2007, pp. 944-954, 2007
- WELING F., JONSSON B. AND DEMERY D., *Proc. 6th World Telecommunication Exhib. and Forum*, Geneva, Switzerland, Oct. 1991
- WIETFIELD CHRISTIAN AND ROKITANSKY CARL-HERBERT, “*Performance of Vehicle-Roadside Communication Systems supporting Multiple RTI-Applications*”, Communication Networks, Aachen University of Technology, 1994
- WISCHHOF LARS, EBNER ANDRÉ, ROHLING HERMANN, LOTT MATTHIAS AND HALFMANN RUDIGER, “*SOTIS - A Self-Organizing Traffic Information System*”, Proc. 57th IEEE Semi-annual Vehicular Technology Conference, VTC 2003 - Spring, Jeju, South Korea, April 2003
- WISETRIP Consortium, *Deliverable D2.1: Report on the analysis of requirements*, WISETRIP Project- 213233, DG TREN, 2008
- WRIGHT S.D., AARON S.J., BRAKE J.F., MURPHY S., NELSON J.D., *DESTINO User Guide*. Internal Working Paper, TORG, Newcastle University, 2007
- YANG XUE, NITIN H. VAIDYA, JIE LIU, FENG ZHAO, University of Illinois - Microsoft Research, US. Patent No. 5,613,039, 1997
- ZIJDERHAND F. AND BIESTERBOS J.W.M., “*Functions and applications of Socrates: a dynamic in-car navigation system with cellular radio-based bi-directional communication facility*”, Proc. VNIS Conference, Yokohama, 1994
- ZOGRAFOS K.G., ANDROUTSOPOULOS K.N., *Algorithms for itinerary planning in multimodal transportation networks*, IEEE Transactions on Intelligent Transportation Systems 9 (1), pp. 175-184, 2008
- ZOGRAFOS K.G., SPITADAKIS V., and Androutsopoulos K.N., *An Integrated Passenger Information System for Multimodal Trip Planning*, Transportation Research Record : Journal of the Transportation Research Board (to appear), 2009
- Zografos K.G., Spitadakis V., and Androutsopoulos K.N., *Assessing an on-line passenger information system for multimodal trip planning*, Proceedings of the 10th International Conference on Application of Advanced Technologies in Transportation, Athens, Greece

Web sites

Travel & trip planners

www.busview.org/busview_launch.jsp

University project displaying Real-time transit locations in King County, Washington (USA)

www.cityrail.info

CityRail trip planner in Sydney (AU)

www.eu-spirit.com

A cross-border European travel information system offering the calculation of door to door travel itineraries between European cities (currently available in Denmark, Germany, Luxembourg and Sweden)

fahrplan.oebb.at

SCOTTY, the journey planner of Austrian Railways (ÖBB)

www.journey.fi

Multimodal (trains, buses) trip planner covering the whole Finland (FI)

maps.google.com/transit

Free journey planning in several cities in the world, by Google

ojp1.nationalrail.co.uk

National rail trip planner in the UK

reiseauskunft.bahn.de

The journey planner of German Railways (DB)

www.romanse.org.uk

Traffic information and events in Hampshire County (UK)

routeplanner.9292.nl

Co-modal public transport planner and information in The Netherlands

www.skandetrafiken.se

Co-modal public transport travel planner and information services (SE)

www.tmb.cat/vullanar/en_US/vullanar.jsp

Route planning in Barcelona (ES), by TMB public transport operator

transit.511.org/tripplanner

Trip planner of San Francisco Bay Area 511 (US)

www.translink.bc.ca

Vancouver Translink trip planner (CA)

www.transportdirect.info

Another popular Britain's free online journey planning, travel news, train times and other

www.traveline.org.uk

UK online public transport information and planning by a partnership of transport operators and local authorities

tripplanning.calgarytransit.com

Calgary Transit trip planner (CA)

www.vbbonline.de

Public transport information, timetables and journey planning in Berlin region

www.wmata.com

Trip planner of Washington Metropolitan Area Transit Authority (US)

Public Multi Modal Travel and Traffic Information Services

www.511ny.org

Travel, traffic and transit information in New York State (US)

www.5t.torino.it

316 Multimodal traffic and travel information in Turin by 5T (IT)

www.anachb.at

Multi-modal transport information and services in Vienna Region, Lower Austria and Burgenland

www.anwb.nl/verkeer

Traffic information in The Netherlands

www.atac.roma.it

Public Transport info services by ATAC in Rome (IT)

www.autostrade.it/autostrade/traffico.do

Traffic information and events in Italy, by Autostrade SpA motorway operator

www.bayerninfo.de

Traffic and mobility information in Bayern Region (DE)

www.ctm-madrid.es

Public transport information by CTM in Barcelona (ES)

www.cities.munimadrid.es/mapatraficovi.asp

Traffic flow data for Madrid (ES)

mobile.atac.roma.it

Mobile Public Transport info services by ATAC in Rome (IT)

www.mobilitypoint.it

Real-time travel and traffic information in Genoa (IT)

www.nextbus.com

Real-time bus information on maps for several US sites

oe3verkehr.orf.at

Map based traffic information for the whole Austria, by ORF radio and tv operator

www.rac.co.uk/traffic-information/traffic

Travel and traffic information in the UK, by RAC

www.ratp.info

Co-modal public transport information and journey planning in Paris region.

roadpilot.asfinag.at

Traffic information services for the whole Austria, by ASFINAG motorway operator

www.ruhrpilot.de

Traffic, parking and other mobility information in the Ruhr Metropolitan Area (DE)

www.tfl.gov.uk/tfl/livetravelnews

Live multi-modal travel news in London (Transport for London)

www.traffic.com

Free traffic information services in the USA, by Navteq

<http://trafficalerts.tfl.gov.uk/microsite>

Real-time traffic conditions in London (Transport for London)

www.trafficengland.com

Real-time traffic conditions on England's motorways and major A-Roads

www3.travelinfony.com/carsgoogle

Real-time transportation status in New York State

www.verkeerscentrum.be

Dynamic traffic information in Flanders (NL)

www.vmz-info.de

Multimodal traffic and travel information in Berlin (DE)

<http://wap.adac.de>

Mobile travel and traffic information by ADAC in Germany

www.wsdot.wa.gov/ferries

Washington State Ferries web information system (US)

Commercial Travel and Navigation Service Providers

wap.adac.de

Mobile traffic information services by the German Automobile Club

www.be-mobile.be

Be Mobile, Belgian traffic and mobility information services

www.geosolutions.be

Belgian service provider offering traffic information and various Location Based Services

www.infoblu.it

B2B traffic and travel information services on motorways in Italy, based on Floating Car Data and other sources

www.keepmoving.co.uk

318 UK road traffic information services

www.navigon.com

Navigon AG, provision of traffic information and navigation services in Europe and USA

www.tomtom.com

TomTom, the worldwide player in traffic information and navigation services

www.trafficmaster.co.uk

Traffic information services pre-trip and on-trip in the UK

www.wayfinder.com

Wayfinder Systems AB, provider of navigation services for mobile phones; since 2009 part of Vodafone Internet Services

Programmes, projects and initiatives

www.agata-cagliari.eu

AGATA mobility platform INTERREG IIIB

www.benefitcost.its.dot.gov

ITS Benefits, Costs and Lessons Learned Databases (USA)

www.bhls.eu

Buses with a High Level of Service; COST action

www.connect-project.org

CONNECT, ITS deployment Euroregional project in Central Eastern Europe Countries

www.corvette-mip.com

CORVETTE, ITS deployment Euroregional project in the Alpine area

www.easyway-its.eu

EasyWay, the European ITS deployment project on main TERN (Trans European Road Network) corridors

ec.europa.eu/transport/galileo

GALILEO, the EU initiative for a state-of-the-art Global Navigation Satellite System (GNSS)

ec.europa.eu/transport

DGTREN, EC Transport and Energy Directorate, transport programme

ec.europa.eu/research/transport

DGRES, EC Research Directorate, transport programme

ec.europa.eu/transport/its/road/action_plan_en.htm

EU Intelligent Transport Systems Action Plan

www.emotion-project.eu

eMOTION; a standardized European distributed architecture for multimodal on-trip traffic information; FP6 Transport

ec.europa.eu/information_society/activities/intelligentcar

i2010 Intelligent Car Initiative, the EU action to accelerate the deployment of intelligent vehicle systems

www.frame-online.net

FRAME, the European ITS Reference Framework Architecture

www.interreg4cflipper.eu

FLIPPER project, about Flexible Transport Services; INTERREG IVC

www.in-time-project.eu

European pilot project for a standardized architecture enabling interoperable Travel and Traffic Information Services; ICT-PSP programme

www.linkforum.eu

LINK, the European forum on intermodal passenger travel; FP6 Transport

www.quantis-project.eu

QUANTIS, Quality Assessment and Assurance Methodology for Traffic Data and Information Services, FP7 project (DGTREN)

www.transurban.org

INTERREG IIIC project on urban transit systems

www.wisetrip-eu.org

Large scale multimodal journey planning and on-trip information for long distance travelling; FP7

Standards, standardization bodies

www.car-to-car.org

The European Car-to-Car Communications Consortium aiming at the development of an open European standard for cooperative Intelligent Transport Systems

www.cen.eu

320 CEN, the European Committee for Standardisation

www.datex2-org

The European standard for traffic information exchange

inspire.jrc.ec.europa.eu

INSPIRE, the European initiative for an EU-wide standardized geospatial information and services infrastructure

www.journeyweb.org.uk

JourneyWeb, UK-originated de facto standard for journey planners

www.naptan.org.uk

NaPTAN, the National Public Transport Access Node database, the UK standard describing the point of access to Public Transport

www.opengeospatial.org/standards/ols

Location referencing open standard promoted by the Open Geospatial Consortium (OGC)

www.siri.org.uk

SIRI (Service Interface for Real Time Information) a CEN standard for exchanging real-time information about public transport services and vehicles

www.tisa.org

TISA, Traveller Information Services Association, the new non-profit organisation taking over TMC activities concerning the development of TMC and TPEG standards

www.tmcforum.com

TMC Forum, the non-profit organisation supporting development and promotion of TMC, the EU standard for broadcasting real time traffic and weather information on Radio Data System (RDS)

www.transmodel.org

TRANSMODEL, the European pre-standard for Public Transport data modeling

List of acronyms - Glossary

A

AC	- Access Control
ACS	- Access Control System
ADSL	- Asymmetric Digital Subscriber Line
AFC	- Automatic Fare Collection
AFMS	- Advanced Fleet Management System
AGATA	- Multi-services AGENCY based on telecommunication centres for the integrated management of mobility and of Accessibility to Transport services, project funded under the European INTERREG IIIB MEDOCC programme
AHS	- Advanced Highway System
AID	- Automatic Incident Detection system
AM	- Ante Meridiem
ANN	- Artificial Neural Network
APTS	- Advanced Public Transportation System
ATIS	- Advanced Traveller Information System
ATMS	- Advanced Traffic Information System
AVCS	- Advanced Vehicle Control System
AVL	- Automatic Vehicle Location
AVM	- Automatic Vehicle Monitoring system

B

BCA	- Benefits Costs Analysis
BHLS	- Bus High Level Services

- BI - Buffer Index
- BN - Bayesian Network
- BRT - Bus Rapid Transit
- B2B - Business To Business services
- B2C - Business To Consumers services

C

- CCTV (TVCC) - Closed Circuit TeleVision
- CD - Compact Disk
- CDU - Urban Distribution Centre
- CEN - Comité Européen de Normalisation (French: European Committee for Standardization)
- CERTU - Centre d'études sur les réseaux, les transports, l'urbanisme et les constructions publiques, French Centre for the research on network, transport and urban development
- CHAID - CHi-squared Automatic Interaction Detection
- CIVITAS - City VITALity Sustainability, initiative of the European Commission helping cities to achieve a more sustainable, clean and energy efficient urban transport system
- CNG - Compressed Natural Gas
- COST - Intergovernmental framework for european COoperation in Science and Technology
- CRA - Costs Revenues Analysis
- CTQ - Compania de Transporte de Quito, Public Transport Operator for Quito Metropolitan area
- C2CC - Car-to-Car Communication
- CVO - Commercial Vehicle Operation

D

- DAB - Digital Audio Broadcast
- DATEX - DATa Exchange
- DEC - Data Elaboration Centre
- DESTINO - DEcision SupportT framework for flexibly delivered public transport services, UK research project
- DLP - Digital Light Processing
- DMT - Quito Metropolitan Department of Transport
- 324 DNT - Ecuadorean National District for Traffic and Transport

- DRG - Dynamic Route Guidance
- DRT - Demand Responsive Transport
- DSS - Decision Support System
- DT - Decision Tree
- DVB - Digital Video Broadcasting

E

- EBU - European Broadcasting Union
- EC - European Commission
- ECM - Evaluation Committee Members
- EDGE - Enhanced Data for GSM Evolution
- eMOTION - Europe wide multi-Modal On-trip Traffic InformatiON, initiative co-funded by the European Commission under the thematic area Sustainable Development, Global Change and Ecosystems of the 6th Framework Programme for Research and Development
- EMMPOQ - Empresa Metropolitana de Movilidad y Obras Publicas, Quito Metropolitan Department of Mobility and Public Works
- EMSAT - Empresa Metropolitana de Servicios y Administracion de Transporte, Quito Metropolitan Department for transport management
- ENEA - Ente Nazionale Energia Atomica, Italian National Agency for New Technologies, Energy and Environment
- EPM - Environmental Monitoring system
- ES - Emergency Service
- ETSI - European Telecommunications Standard Institute
- EU - European Union

F

- FAMS - Flexible Agency for collective demand-responsive Mobility Services, project funded under the European Commission Fifth Research and Development Programme
- FC - USA Federal Communication Commission
- FL - Fuzzy Logic
- FM - (1) radio Medium Frequency (2) Fleet Management
- FP - Framework Programme for European common space of research and development
- FTS - Flexible Transport Services
- FV - Frequency Variability indicator

G

- GDF - Geographic Data Files
- 3G - Third Generation Mobile Communication
- GIP - Graph Integration Platform
- GIS - Geographic Information System
- GNSS - Global Navigation Satellite System
- GPRS - General Packet Radio Service
- GPS - Global Positioning System
- GSM - Global System for Mobile communication
- GUI - Guided User Interface
- GVFG - Gemeinde Verkehrs Finanzierungs-Gesetz, Community Transport Financing Act in Germany

H

- HSDPA - High-Speed Downlink Packet Access
- HGT - Heavy Goods Transportation
- HTTP - HyperText Transfer Protocol
- HW - HardWare equipment

I

- ICT - Information Communication Technologies
- ID - IDentification number/address
- INVETE - Intelligent In-Vehicle Terminal For Multimodal Flexible Collective Transport Services, project funded by the European Commission under the Fifth Research and Development Programme
- IRTE - Integrated Road Transport Environment
- ISP - Internet Service Provider
- IT - Information Technologies
- ITS - Intelligent Transport System
- IVHS - Intelligent Vehicle Highway System

J

- JTRC - OECD Joint Transport Research Centre

K

- 326 KNN - K Nearest Neighbour

KOMODA - CO-MODAlity - towards optimised integrated chains in freight transport logistics, project launched by the call TPT 2007.2 of the Seventh Framework Programme and funded by the European Commission

L

LAN - Local Area Network
LBS - Location Based Service
LCD - Liquid Crystal Display
LOC - LOCation referring system
LOS - Level of service
LRM - Location Referencing Methods
LTP - Local Transport Plan
LTZ - Limited Traffic Zones

M

MAC - Medium Access Control
MAE - Mean Absolute Error
MAPE - Mean Absolute Percentage Error
MASCARA - Flexible mobility services for social cohesion and rural accessibility, project funded under the European INTERREG IIIC West Programme in 2005
MEDOCC - The European INTERREG IIIB Programme for Western (Occidental) Mediterranean Countries
MEROPE - Intelligent system for logistics and mobility services in urban and metropolitan area, project funded under the European INTERREG IIIB MEDOCC in 2003
MIUR - Ministero Italiano Università e Ricerca, Italian Ministry for Research
MLN - Multiple Linear Regression
MTA - Mobility Transport Act
MTBF - Medium Time Between Failure

N

NaPTAN - National Public Transport Access Node database

O

OCSE - OECD- Organisation for the Economic Cooperation and Development
OFDM - Orthogonal Frequency Division Multiplexing
OGC - Open Geospatial Consortium

P

- PC - Personal Computer
- PDA - Personal Digital Assistant
- PGTU - Urban Transport and Mobility Plan
- PKI - Public Key Infrastructure
- PMS - Parking Management System
- PND - Personal Navigation Device
- POI - Point Of Interest
- POR - Operative Regional Programme, ERDF Objective 1 programme managed by Italian Region
- PRN - Private Radio Network
- PM - Post Meridiam
- PTI - (1) Public Transport Information message (2) Planning Time Index
- P&R (P+R) - Park and Ride services

Q

- QMD - Quito Metropolitan District- Ecuador
- QoS - Quality of Service

R

- RDS - Radio Data System
- RDSS - Regional Data Services Server
- RFID - Radio Frequency Identification
- ROM - Read Only Memory
- RSU - Road Side Unit
- RTDMA - Random Time Division Multiple Access
- RTI - Road Transport Informatics
- RTM - Road Traffic Message
- RTPI - Real-Time Passenger Information
- RVM - Relevance Vector Machine

S

- SAMPO - Systems for Advanced Management of Public transport Operations, funded in EU Programme TAP, Telematics Applications Programme

- SAMPLUS - Systems for the Advanced Management of Public Transport Operations, follow up of the former SAMPO project
- SDMA - Space Division Multiple Access
- SHDLS - Symmetric High-speed Digital Subscriber Line
- SIM - Mobility Information System
- SIPTS - Services for Intelligent Transport System, project funded under EU eTEN Programme
- SIR - “Saggio Interno di Rendimento” italian acronym for the “value making VAN function equal to zero”
- SIRI - Service Interface for Real-time Information
- SIT - Geographic Information System
- SLA - Service Level Agreement
- SMS - Short Message Service
- SOTIS - Self Organizing Traffic Information system
- SROI - Social Return to Investment
- SUNRISE - Cohésion sociale dans les zones urbaines/rurales basée sur services collectifs de mobilité innovateurs et durables, project funded under the EU INTERREG IIIC Co-operation Programme
- STM - Strategic Traffic Management system
- SVM - Support Vector Machine
- SW - SoftWare tool

T

- TCC - Traffic Control Centre
- TDC - Travel Dispatch Centre
- TDMA - Time Division Multiple Access
- TEMPO - Trans-european intelligent transport systEM PrOject, programme launched by European Commission in 2001
- TERN - Trans European Road Network
- TETRA - TErrestrial Trunked Radio communication
- TIC - Traffic Information Centre
- TISP - Traffic Information Service Providers
- TISA - Traffic Information Service Association
- TMC - Traffic Message Channel

- TPEG - Transport Protocol Expert Group
- T2E - Transport To Employment service
- TTI - (1) Travel and Traffic Information (2) Travel Time Index
- TTIS - Travel and Traffic Information System
- TU - Technical Unit of the European Commission
- TVM - Trans Val de Marne

U

- UEFA - Organisation of European Football Association
- UITP - International Association of Public Transport
- UMTS - Universal Mobile Telecommunication System
- UTC - Urban Traffic Control
- UTT - Urban Travel Times
- UWB - Ultra Wide Band technologies

V

- VAN - Valore attuale Netto, Italian acronym for Net Present Value
- VDV - Verband Deutscher Verkehrsunternehmen, founding of the Association of Germany Tramway and Light Railway
- VEMA - Viennese Traffic Management Initiative
- VHF - Very High Frequency
- VIRGIL - Verifying and strengthening rural access to transport services, project funded under the EU Research and Development FP4 Programme
- VMS - Variable Message Signals
- VPN - Virtual Private Network

W

- WAN - Wide Area Network
- WAP - Wireless Application Protocol
- WiMAX - Worldwide Interoperability for Microwave Access
- WLAN - Wireless Local Area Network
- W3C - World Wide Web Consortium

X

- 330 XML - eXtensible Markup Language

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