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Invited Review

The application of information and communication technologies in transport

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Abstract

This paper examines the possibilities that are opened today and for the whole decade from the application of Information and Communication Technologies (ICTs), in the field of Transport. The various applications are examined, under the following three headings: operation and management of networks (all modes), information and guidance to the users (of the transport systems), operation and management of freight transport systems.

For each of these, a concise and critical review is made of the various technologies that exist today in their final stages of development or at the stage of commercial implementation, and their applications. The review refers to various sub-categories of the above main three.

The paper proceeds then to examine the prospects for the future with a medium time horizon of 2010. These prospects show that a number of areas of applications have well established technologies and are secured of commercial viability so that we can predict safely their full scale application in the course of this decade. Examples of such areas of applications are: traffic data information collection and dissemination systems, network control and traffic management strategies, vehicle control and driver assistance, systems for (Electronic or other) fee collection.

And specifically for freight: freight resource management; terminal and port information and communication systems, freight and vehicle tracking and tracing, and "front" or "back-office" logistics systems.
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1. Introduction

The term "*Information and Communications Technologies* (ICT)" is used to delineate the various Telecommunications and Information Technologies, which have been used in the field of Transport since the mid-80s. They include a large number of technologies and systems in various stages of development from research prototypes or even concepts, to commercially available products and applications.

The past decade (the 1990s) saw a rigorous development of such prototype technologies and systems and also of their applications in the field of Transport. Notions such as the "intelligent vehicle", the "intelligent highway", or "smart real time traffic monitoring and control", were introduced

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for the first time to express the increasing "intelligence" and dynamic nature of the systems that were introduced.

A major research effort on the part of the EU was initiated in 1988 with the main objective to assist in the application of new technologies in the field of Transport (road transport in the very beginning) for safety and efficiency. This was programme DRIVE of DG XIII (now DG INFSO). Almost at the same time similar research started in the US and Japan.

In the years that followed, i.e. all through the 90s, EU sponsored research in "*Transport Telematics*" continued primarily under the auspices of Directorate General Information Society (DG INFSO) but in the later part of the nineties also under the auspices of DG TREN (Transport and Energy). [1] This effort was spread over four periods of 4-year research programmes [2] that coincided with the second, third, fourth, and fifth so called Framework Programmes of research funding by the EU (for short second, third, fourth, fifth, FPs). The first period was known, as already mentioned under the name of "DRIVE", the rest ones as advanced transport telematics (ATT), and transport application programme (TAP).

For each research period there is an overall programme report published. This report gives an overview of the programme and a summary of the results of the individual research projects. For the fourth FP this report, also known as the *concertation and achievements report of the transport sector* (CARTS) report, is the latest publication of that kind [1]. For more documents and deliverables of the various EU supported research projects in the field of Transport Telematics, the interested reader is referred to the European Commission's web site: www.cordis.lu/telematics/tap_transport/home.html

Several National (almost in each major European country) or International (such as under the EUREKA framework) research programmes have also been active in the field of Transport Telematics and new Technology applications in the field of Transport. Of these, reference is made only to the German programme (described for example in: *Bundesministerium*, 1999) which by itself had a spending (for the period 1990–1998) approaching almost 2/3 of that of the EU's DG INFSO programme for the same period [2].

Finally, on the official EU policy level, promotion of new Technologies and their applications in Transport ranks prominently in the list of official actions and decisions. Of the 14 priority applications identified as central to the achievement of the *European Information Society*, two specifically addressed the promotion of *intelligent transport systems* (ITS) for road and air transport, while in most of the others one can find elements related (directly or indirectly) to Transport. An action plan [3], proposed by the EC and endorsed by EU Member States, supports private-sector developments aimed at financing and deploying the infrastructure required for its realisation. The EC has also published a number of other related policy documents among which

- *The citizen's network* [4]*:* which outlines means of achieving integrated public transport systems with easy interconnections between networks.
- *Towards fair and efficient pricing in transport* [5]*:* which advocates differentiated transport pricing to encourage more sustainable transport choices.
- *A new approach to maritime strategy* [6]*:* which focuses on shipping registers and common application on internationally agreed rules of safety in which the prominent role of new technologies applications is stressed.
- *Communication on inter-modal freight transport* [7]*:* which proposes optimal integration of different transport modes, to encourage efficient and cost-effective use of the transport system through seamless, customer-oriented door-to-door services and
- *The e-Europe initiative* [8]*:* in which a set of 10 priority actions with target dates are set for the promotion of Information Society in Europe.

[1] Although the main objective of this programme was Transport policy issues, a substantial part of the various projects dealt with issues regarding the application of new technologies in the field of Transport.

[2] Including the current one which ends in 2006.

Currently (December 2002) the new, sixth Framework Programme for research is being lounged by the EU. Within this new programme a large proportion of funds is allocated to Transport research. Of primary importance within the published work programme are applications of ICT in the field of Transport. The expected work is allocated among three DGs: DG RTD, DG TREN, and DG INFFSO. It is expected that new systems and applications in the field of Transport for 2010 and beyond will be developed within this sixth Framework Programme.

This paper attempts to provide a more global, and in a sense more critical, view of the achievements of research on new technology applications in the field of Transport (all modes). At the same time it hopes to provide an objective view of the prospects for this new decade, and the wider horizontal issues that are involved. In doing so, it follows by and large the terminology and categorization, of the various applications and technologies, followed in the EU research programmes. [3]

2. Current and prospective outlook of ICT applications in the field of transport

2.1. Technology baseline

The technologies that emerged commercially during this last decade and which had a marked impact on the way Traffic and Transportation is currently shaped, are the following:

- GSM (the European system for mobile telephony and data transfer) and other relevant technologies for mobile communications and positioning;
- Broadband communications;
- First and second generation Internet services;
- Dedicated short-range communications (DSRC);
- General packet radio services (GPRS);
- A series of continuous improvements in terms of speed and capacity for computers and software.

The list of these technologies is not meant to be exhaustive. It rather serves as a checklist and reminder of the major technological lines of development in the nineties, which saw most of the specific applications in the field of Transport.

The various Transport applications are examined, in this paper, under the following three main headings:

1. Operation and Management of Networks (all modes).
2. Information and guidance to the Users (of the Transport systems).
3. Operation and Management of Freight Transport systems.

The above categorization is chosen because it covers in a kind of horizontal way, practically all, or almost all, of the many fields and types of transport whichever way one chooses to see them (e.g. person trips vs freight, or through a modal perspective, etc.).

2.2. Operation and management of transport networks

2.2.1. Road networks

Road Traffic Management and Control Systems have been operating in Europe for many decades, emerging from individual single control systems to highly integrated network systems. Urban and Interurban Control Systems, which address different road traffic users and characteristics, are becoming more and more connected and integrated. The main objective is primarily on enhancing road safety, but other objectives such as improving efficiency and environmental aspects are also followed up.

The "elements" that constitute the current road network operation and management "environment", either in the urban or interurban context, can be grouped in the following four areas (see Fig. 1):

[3] This author, has been involved heavily for the last decade in many EU research projects as well as on the administration and policy formulation activities of the whole Transport Telematics programme.

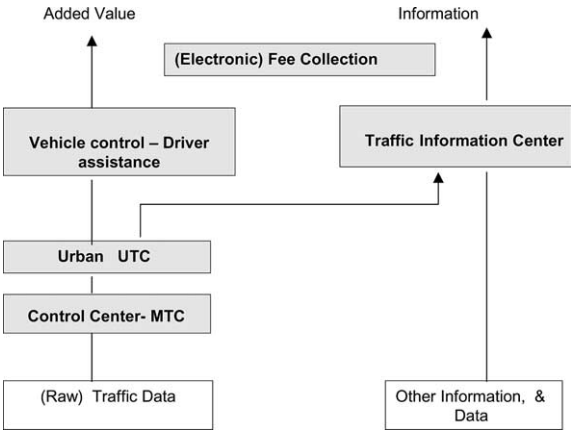

Fig. 1. The "elements" in the road network operation and management "environment".

1. Traffic Data and Information collection and dissemination systems;
2. Network control and traffic management;
3. Facilities and systems for Vehicle control and driver assistance;
4. Systems for (Electronic or other) fee collection.

Within the *Traffic Data and Information collection and dissemination* area, data and other (primary) information is collected, analysed, and made available to the various users of such information through a variety of means and mediums. *Traffic Information Centres* (TIC) make use of traffic related data, adding further useful information and data in order to produce, and have available, so-called "added value data" which could be used for user information purposes (see also previous section on person trips and traveller information).

Examples of the type of Information usually supplied are as follows:

Dynamic information:

- congestion areas;
- accidents and incidents;
- road works;
- weather conditions;
- specific events (and related forecasted congestion e.g. football matches),
- waiting hours or other procedures when approaching border crossings (where borders exist).

Static information:

- expected traffic volumes on specific road sections at specific time periods;
- information on bank holidays, school holidays, etc.;
- information on specific regulations (e.g. winter tyre obligations etc.);
- existing speed limits;
- levels of road fees;
- general information on other modes (airports, rail, public transport).

Other (either static or dynamic):

- information on ferry links;
- information on parking guidance and Park-and-Ride systems;
- information on car sharing (car pooling).

The *network control and traffic management* area includes all tools and systems needed to fulfil guidance and access control requirements as well as the various traffic management applications and strategies. They also include methods and means to improve our understanding of network conditions for both inter-urban and urban situations. Integrated, co-operative network control and management strategies have been demonstrated (originally) and are gradually implemented at a large number of sites across Europe. [4] The most "mature" systems that are expected to be in application in an increasing number of sites in the next few years, are the following:

- congestion and incident management systems to enhance traffic-adaptive control systems as well

[4] Many EU funded research projects (fourth and fifth FP) have provided such demos and pilot applications (see for example projects QUARTET PLUS, TABASCO, CAPITALS, EUROSCOPE).

as the associated emergency response management;
- other types of congestion management systems based on artificial intelligence and ramp metering;
- new algorithms to control intersections (new local controller architecture with standard interface module);
- new operational strategies for driver information and guidance;
- innovative access control systems (e.g. based on license plate recognition).

Network control and Traffic Management functions are carried out through:

Urban Traffic Control (UTC) systems, such as for traffic light control, parking advice and control, mandatory direction signing and route guidance etc. and

Motorway Traffic Control (MTC) systems, such as for traffic speed control, incident/accident warnings, overtaking restrictions, weather related instructions etc., are all based on many static and dynamic (online) traffic data which has been mainly collected in the past by inductive loop detectors.

In this area (of Traffic Management strategies) one could also include the case of special collective transport management and information systems, including traffic management for traditional public transport vehicles and more innovative services based on door-to-door mobility solutions. Research into *demand responsive transport* (DRT) has investigated ways of providing flexible transport services, including technologies, user acceptance, institutional and organisational aspects, business case development and best practices. Demonstrations of DRT systems and services have been carried out in Europe over the last 5 years e.g. in the Limburg Region (Belgium), the Uusimaa and Seinjoki regions (Finland), Florence and Campi (Italy) and Gothenburg (Sweden). [5]

As regards *facilities and systems for Vehicle control and driver assistance* here applications such as speed control, collision warning and avoidance and lane-keeping support are included. Autonomous driving applications have been successfully demonstrated within the pre-mentioned EU supported research Framework Programmes, using the concept of the 'electronic tow-bar'. [6] The trials were set up between two lorries (initially) while subsequently for more, forming a platoon. Trials have also been made for autonomous driving or automated platooning systems. These systems raise a number of non-technical issues such as consumer confidence, system dependability, testing and certification, regulatory implications, liability and other legal aspects. Their application in every day practice is therefore still many years ahead.

In this area of ICT applications (i.e. for vehicle control and driver assistance) one should also include the use of automatic vehicle location technologies using either GPS, or digital mobile communications between travel dispatch centres and drivers, or use of smart cards to pay for services and act as an identity system when automatically reserving return trips.

Finally, and in view of the increasing privatisation of the motorway networks, *electronic fee collection* (EFC), is becoming a major "element" (that merits separate mention) of the road network control and management area of applications. The main systems to date are DSRC based systems operating at the 5.8 GHz frequency, but the necessary road infrastructure is heavy and expensive. GPS/GSM systems are also available to support EFC applications, with standards already in place. These dispense with the need for roadside infrastructure.

Interoperability of EFC systems is a key requirement for Europe. [7] The topic is one of primarily setting up common technical standards (and already such standards have been issued by

[5] Such was for example the demos by DG INFSO fourth FP project SAMPO/SAMPLUS.

[6] See for example the results of DG INFSO fourth FP project CHAUFFEUR.

[7] This was recognised as an official EU policy since 1998 for achieving the EU's goal of fair pricing for infrastructure charging. Relevant actions were presented in December 1998 to the European Parliament and the Council in a Communication from the EC (reference 785/98).

CEN in Europe following the work of the CARDME and other EU funded research projects). Besides the technical standards, contractual agreements between operators, common requirements for transactions, and other specific issues (e.g. the technical and legal aspects of cross-border enforcement of traffic violations) are also needed.

Extensive site tests have taken place in the UK, Germany, Portugal, and France (e.g., at Orleans and Bretigny sur Orge–France, Cologne–Germany, London–UK, and Cascais–Portugal) with the aim of measuring the performance of standards, and demonstrating the possibility of coexistence, at the same toll plaza, of both DSRC equipment and other (e.g. low-data rate system operating at the same frequency). On the issue of contractual interoperability, a Memorandum of Understanding has been developed between operators and the banking sector [8]. Currently, the issue of interoperability of toll collection systems in Europe is finalised by project CESARI. This is performed through EU funding by a consortium headed by the European Federation of Toll Collection Agencies and Authorities (called ASECAP) and with the participation of the majority of European Toll collection Authorities.

2.2.2. Railway networks

The operation and management of the railway network calls for the provision and management of routes, schedules (actual time of operation within a 24 hour period) and transit times for the operations. In classic rail terms this involves the actual management of the infrastructure through *scheduling, signalling, train planning and control mechanisms*. All of these interact to facilitate the actual operation of trains.

The transport operation on the railway network aims to assure that operations are undertaken with due regard to safety, speed, schedule reliability, efficient routing, and competitive (point to point) travel times. For these basic objectives to be achieved, railway management and operation must ensure the integrity of the track and structures, power supply and signalling systems as well as a number of complex inter-actions in the provision of the traffic supply, capacity, and capability. Rail networks stand therefore in complete contrast to road networks in that an operator can access the infrastructure and traffic environment of the second without prior notification and without any due regard of the consequences of that action in terms of traffic load, congestion, imposed delay etc. This cannot be done in rail networks.

Here we have a "linear" and totally planned environment within which trains operate. They do not have the ability to change direction or line of route without the intervention of some form of traffic control (signals and points/switches) and they have to maintain key separation distances imposed by train speeds, acceleration and braking capability. On top of this restrain, further complications arise (with serious consequences for both traffic and transport on the rest of the network) by the operation of scheduled and unscheduled services as well as the management of emergencies and deviations from the pre-planned schedules. Trains operating over lines, routes or systems operate in response to a planned infrastructure capacity managed such as to allow trains to adhere to the publicised or advised schedule. The operation of additional services around the scheduled trains or the handling of delays and/or emergencies implies a management capability to facilitate these additional activities and not to compromise the operation of the rest of the scheduled services. The allocation of priorities to trains by type, schedule and relative priority, set a hierarchy which in the event of de-stabilisation of services is not always easily recognised in the recovery phase.

To further "complicate" things, the new operating and organisational framework for the railways [9] requires the separation of infrastructure provision as relates to the (commercial) service provision [9]. There are therefore an increasing

[8] Produced by fourth FP DG INFSO project MOVE-IT.

[9] See also the Railway Infrastructure Package (Directives 91/440, 95/18, 95/19); and the Directive on the Interoperability of the Trans-European Conventional Rail System adopted by the European Parliament and European Council in 2000.

number of "actors" involved and operating constraints to be taken into account.

In view of the above, the introduction of the application of "new technologies" in the railways has been rather slow so far, but at the same time its importance and great potential in helping to solve the complex and demanding issues mentioned before has been recognised by all sides involved.

One of the key issues is the communication of information between trains and the infrastructure or in the new operating environment's terminology: between train service operators and infrastructure owners and/or operators. In the traditional environment, where trains operate without train to ground data links, a train was required to halt at a signal and communicate by phone to a signal box for instructions (usually issued under a codified rules system) in the event of a complication or problem with the running order of trains. On single-track operations the management of train movement between crossing points or loops to avoid collisions and to maintain high infrastructure productivity there is an enhanced requirement for bi-directional signalling and communications. The advent of modern train Centralised Traffic Control (CTC) and Train Communication Networks (TCNs) as well as a host of other new technology applications have achieved significant advances in the safe schedule and train traffic manipulation, as well as increasing speeds, line capacity and reducing delays.

Train movements on a modern railway network management and control system are monitored, by either the signalling system or by various train monitoring systems, which may be proprietary or unique to individual national networks. Trains are accorded unique train reporting numbers, which identify the trains for the duration of their particular operation. The trains' progress, location and time keeping is logged and this information is used by individual train operating companies and major shippers to identify where their equipment is (with varying degrees of accuracy). The existing systems range from very simple train tracking using the signal circuitry in the track as the message movement medium to more sophisticated systems which track the train or individual vehicles using satellites, or beacons along the route, or various other methods. The move from train tracking to a more complex *asset management* system to drive up vehicle productivity has only begun to be addressed as a wider rail network traffic management issue.

Most of the focus of new research on the application of new technologies in Transport the last 4–5 years (fourth and fifth EU FP as well as National programmes) has been on interoperability and standardisation issues as well as towards achieving a pan-European Railways Data and Information transfer network. The *European Rail Traffic Management System (ERTMS) is the common* European railways traffic management and communications system that has been developed and applied by the major European railway networks. Communications are achieved by means of GSM-Railways (GSM-R) technology. [10] Development and conformance testing of GSM-R prototypes took place on French, German and Italian trial sites in co-operation with the ERTMS Users Group. [11] Some of the most representative functions of the ERTMS include: location-dependent addressing, numbering, presentation of functional numbers and confirmation of priority calls, voice broadcast, voice group call and enhanced multi-level priority and pre-emption. [12] What had been achieved at the end of the last Framework Programme, is:

- UIC (International Union of Railways) specifications and a conformance testing (UIC ref nos 556, 557, 647) for an open gateway communication, system (called ROGATE) which is able to interconnect the on-board TCN with a ground network based on the TCP/IP protocol by means of a GSM/GSM-R radio link.

[10] GSM-R enhances standard GSM technology to comply with railway requirements (as defined by the International Union of Railways (UIC) in the EIRENE project), so guaranteeing interoperability and integration with ERTMS architecture.

[11] This took the form of a legal entity called a European Economic Interest group (EEIG), and it took over Phase 2 testing under the EU's TEN-Transport Programme.

[12] See also EU's fourth FP, DG INFSO project MORANE.

- On-board GNSS positioning prototypes have also been successfully developed and tested. [13]
- Conflict detection and resolution applications [14] related to the ERTMS.
- Remote monitoring and maintenance applications [15] have also been addressed.

2.2.3. Waterborne transport

The research activity on ITS applications for ports and waterways can be divided into 3 areas as follows:

1. ship communications and management information;
2. interoperable maritime traffic management and navigation services;
3. improved resource management at ports.

Improved *on-board (the ship) communications management* applications include development and operation of a single data node capable of dealing with expected increases in maritime data flows arising from new technologies such as radio-transponders for vessel traffic service management, electronic chart displays and information updates, and maintenance management. Prototype commercial systems for the collection and distribution of electronic navigational charts have been demonstrated [16] while ship safety information management and support systems have been applied in order to comply with international safety and quality management systems with ship-to-shore communications. It must be stressed here that there is a lot of communication going on from ship to shore and vice versa. Especially in port areas this communication can add up to very heavy communication, with possible results in misunderstandings and loss of important information. Particularly in bad weather conditions this, together with stress situations could end in dangerous situations/accidents. So the applications that concern the on-board communications management are likely to be expanded in the future.

Waterborne *Traffic Management and Control systems* have had a major development in the last few years from operating through radio stations around the coastlines to satellite communications and today's VTS centres. Several EU Member States have at the moment *Vessel Traffic Services* (VTS) systems that are however, at the moment mutually incompatible and inhibit the transfer of important safety-related information from one system to the other. Tools, principles, standards and architecture for the interoperability of VTS at local, regional and European levels have therefore been a major research area, [17] and a concept for integrated Vessel Traffic Management and Information Services (VTMIS) has been developed and demonstrated to rationalise the current multiplicity of on-board communication systems. VTMIS information on the Internet and VTMIS information recording and decision-support tools have been demonstrated in co-operation with the International Maritime Organisation (IMO).

The various VTS functions that can be found on operation around Europe are:

- Information services (covering general fairway and traffic conditions, special events, weather and tidal conditions and forecast). These are provided as a broadcast service or on request by individual vessel.
- Navigational assistance services (considering vessel position relative to fairway or channel, traffic in vicinity, track advice, warnings). These are provided as a navigational support to individual vessels including remote pilotage.

[13] To be further developed and integrated with the development of the European satellite based positioning and communication system GALILEO.

[14] For example fourth FP project MARCO dealt with rail and mass transit applications, detecting traffic conflicts and suggesting optimised solutions in both high-traffic and geographically wide areas. Also project COMBINE addressed 'moving block' section issues in relation to instabilities in train speed profiles.

[15] Supporting tasks such as remote maintenance and commissioning, remote diagnostics, freight-train payload description, cross-border information, and data downloaded from safety black boxes.

[16] As for example in fourth FP project COMMAN.

[17] See for example fifth FP projects IDES, and VTMIS-NET.

- Traffic organisation services (aiming at traffic monitoring and control, traffic prediction, space allocation to vessels, enforcement of law and regulation, other authoritative measures) addressing individual vessels or a collective of vessel.
- Co-operation with allied services for exchange of information in order to allow resource planning in areas such as pilot, tug or mooring services and administrative operations from customs, immigration, police and health services.

The numbers of VTS centres in Europe are increasing but wide areas are still without any kind of VTS functionality. The areas covered today are mainly in strong traffic sectors and in dangerous fairways. These VTS centres operate even today largely isolated without any communication and information exchange between them. The trend for Traffic management in the waterborne area is that systems will exchange more data with each other. Reaching total integration is however still far off but it can be said that the process to exchange data has started.

The most relevant current technologies for the management of Maritime traffic are:

- Global positioning system (GPS), a satellite-based navigation system which provides continuous position.
- Electronic Chart Display and Information systems (ECDIS). This is a system to operate and visualise digital navigation chart data.
- Satellite-based communication systems (such as for example INMARSAT) with almost global coverage, the maximum transmission speed currently being 128 Kbytes/s by connecting two B-channels.
- Automated Identification Systems (AIS). These are used for the automatic identification of a vessel and its coordinates. They invariably consist of a radio transponder allowing broadcasting vessel data in a fixed format and to a restricted extent also free text messages. Those messages can be transmitted automatically or polled by a shore-based entity or another vessel. This is an emerging technology, which will become mandatory for all vessels of more than 500 gross tons between 2002 and 2008 depending on the type of the vessel and the cargo carried.

As regards now the resource *management* at ports, this includes a number of applications such as:

- optimisation of support services such as pilot, tug and mooring services;
- improved organisation of public services such as health, immigration and custom services;
- optimisation of port and terminal services such as berth, loading and discharge services;
- organisation of shipping company and agent services;
- other relevant services.

A very innovative research effort for better resource management at ports was the application of the principles of re-engineering for the re-organisation of small and medium sized ports [10]. This followed an extensive user requirements survey, which covered some 100 ports around Europe [11].

2.2.4. Air transport

In this field, one key area of research work and applications can be distinguished. It concerns the development of Europe's air navigation system that integrates Communications, Navigation, and Surveillance services (CNS) to provide comprehensive Air Traffic Management (ATM) in order to enhance capacity without prejudicing safety. The heart of the future European air navigation and positioning services will be the GALILEO satellite navigation system. This system is the end result of years of research and development that took place for the creation of the so-called European GNSS II, and the Aeronautical Telecommunication Network (ATN).

Another very promising area of developments within the general AIS system area, is the concept of Automatic Dependent Surveillance (ADS) which by using a range of technologies generates automatically the required data (e.g. about the position, speed, direction, etc of an aircraft) and communicates them automatically to ground con-

trollers. ADS-Broadcast (ADS-B) has now been successfully demonstrated [18] to the international air control bodies ICAO and EUROCONTROL. It has also been standardised within ICAO as *VDL Mode 4* system. Its supporters [19] are also promoting VDL mode 4 as a universal system for vehicle-to-station and vehicle-to-vehicle communication system applicable to other modes of transport and not only air. Already extensive applications in maritime transport exist in the Scandinavian countries.

Finally, in the ground operations (i.e. at airports) several European airports (among them Paris–Orly–France and Schiphol–The Netherlands) have been test grounds for validating low-cost airport ground movement systems, [20] with the emphasis on aircraft movement planning and guidance, parking security surveillance, and the maintenance of high levels of safety.

2.3. Information to the users

In their entirety, information to the users applications relate to the transfer of information and data to the various users of Transport services. These are primarily the travelers on the various networks, and the various individuals or companies associated with the movement of goods or the owners of the goods that are transported on the various networks. These applications have to do with the "collection", "creation", and "supply" of accurate, timely, and in increasing number of cases, "real time" data and information to the user.

The scope for providing such information may be wide and varied. It may help a person to plan and execute his (her) trip in the most effective way and at the same time implement a number of policies that have wider positive implications in the use of today's congested networks. [21]

By implementing systems for supplying timely, reliable, and in real time information to the users, a number of possibilities exist for:

1. applying various demand management options (i.e. the possibility to induce people to travel at non-peak hours, use more "traffic friendly" destinations, share vehicles with other travelers, etc.);
2. reducing journey-time uncertainty;
3. choosing the most appropriate connections/interchanges thus maximising use of spare capacity, minimising waiting times, and increasing "Inter-modality" in passenger transport services;
4. making real-time route changes to avoid congestion;
5. encouraging people to change transport modes (especially in urban travel and in favour of public transport); and
6. offering personalised travel information;
7. developing more advanced applications for travel booking and reservation services.

In some application areas, a number of systems are already in existence for several years now. [22] Examples:

- the various enabling systems, such as the Traffic Information Centres (known as TICs), and information platforms and data exchanges (e.g. DATEX);
- the urban and interurban information services and systems (including multi-modal systems using the Global System of Mobile communications (GSM));
- Radio Data System-Traffic Message Channel (RDS-TMC);
- Variable Message Sign (VMS) arrays;
- fixed information terminals;
- hand-held Personal Traveller Assistants (PTAs), and
- internet based services.

[18] By fourth FP project FARAWAY.

[19] Among them the Swedish Civil Aviation Administration and the Swedish Maritime Administration.

[20] As for example in fourth FP project AIRPORT-G.

[21] The same of course holds true for the movement of goods as well. In the following, for simplicity, we refer only to systems regarding "Information to the traveller" but most of them are also applicable to the users of the freight transport networks.

[22] In the previous TAP research period (see also [1]) some 20 projects dealt with travel information, including eight large demonstration projects on multiple sites (see Annex 1).

Looked from another angle information to the user can be divided into two categories:

- *pre-trip*, enabling them to plan journeys on the basis of informed choices (eg: of desirability of travel, routes, transport modes and departure times); and
- *on-trip*, giving confirmatory messages, route guidance and warnings, enabling travellers to adapt trips to actual events and incidents.

As regards the "means" for transferring information to the user, one can make a broader classification as follows:

1. mobile multi-modal travel information devices, e.g. mobile phones, PTAs;
2. fixed devices, either Internet based or other e.g. public access terminals (PATs) at strategic locations and interchanges;
3. in-vehicle driver information and navigation systems, e.g. via on-board computers; and
4. roadside driver information systems, e.g. VMS.

To offer information via these systems, a systematic background infrastructure must exist for the data gathering, processing and management; as well as for the communication and data distribution, and user-friendly human–machine interfaces. In practice, most types of systems offer information through more than one type of device.

2.3.1. Mobile multi-modal travel information devices

The current technology trend, that is likely to continue in the future, is to offer more powerful and versatile applications with portable personal devices once the 3G mobile telephony comes to application (sometime in the next 2 or 3 years). These applications (using advanced mobile phones or palm-top computers) will give access to Internet-based information services such as public transport timetables, route guidance, road and traffic events, as well as real-time alerts on transport or road network conditions. Users will also be able (much more than now) to access booking and reservation facilities and read the latest tourist and destination information.

The evidence so far from various European research projects (e.g. projects PROMISE, INFOTEN, and others fourth FP and project INFOPOLIS II, fifth FP) [23] showed that user acceptance of portable information devices, was generally positive (the view of over two-thirds of the sample of participants). This was based on pilot applications in Finnish, Swedish and UK test sites. Satisfaction levels in France were lower, due to competition from comparable services that were free. Failure rates were very low (between 0% and 7%). Response times (10–70 seconds in those trials) clearly needed to be improved. However, developments such as the increasing use of the wireless application protocol (WAP), and GPRS, as well as enhancements to information database platforms, are expected to change this in the near future as suggested in the previous paragraph. An important finding of trials in Verona (Italy) and the German Land (State) of Bavaria (project INFOTEN, fourth FP) revealed the importance of good and user-friendly user interfaces and suggested that users were *unwilling* to pay more than EURO 10 (approximately) per month for PTA services [1]. Thus the main obstacle for mobile information systems and devices is clearly the cost of communication.

2.3.2. Fixed multi-modal travel information devices

Information can be delivered at fixed locations through the Internet, EDI, or PATs, and using multi-media terminals, display panels and simple terminals like the Minitel in France. All allow the users to access a wide range of static and real-time information, and make enquiries that draw on multiple data sources for trip planning, including maps, public transport timetables and fares, destination information including tourist facilities, booking and reservations services, and alerts on traffic delays and road works. They also allow travellers to modify their journey plans as the need arises. Currently. Large multi-purpose multi-application Internet based information platforms are currently developed [12] which are providing users with both information and application

[23] See [1].

packages that can be very useful for their particular needs.

Current PATs, the Internet, and multi-media terminals allow users to search for information with the help of menus, icons and screen layouts designed for ease of understanding. Guidelines for traveller information display media (which are particularly relevant to fixed multi-modal devices) already exist in Europe through the standardisation process of Technical Committee (TC) 278 of the European standards organisation CEN (CEN TC278). They incorporate also special requirements of the disabled and elderly. [24]

Public access and fixed information terminals have been successfully deployed in several European cities and regions. Examples of systematic large-scale applications are in Southampton (UK), Rome (Italy), Marseilles (France), Valencia (Spain), Gothenburg (Sweden), the Land of Hessen (Germany), Thessaloniki (Greece), and Turin (Italy).

Internet information services have been widely implemented in cities such as Southampton (UK), Gothenburg (Sweden), Munich (Germany), Verona (Italy), Metz (France), Barcelona (Catalonia, Spain), Bremen (Germany) and Bristol (UK); and regions such as South Yorkshire (UK) and Scandia (Sweden). Practically, now, all major European cities have Internet based travel information services in various states of development and technological advance. Though users have often found response and/or download times too slow, they have rated accuracy and reliability of data between 60% and 80% and user acceptance (in terms of ease of use and understanding of information) has typically been rated between 65% and 75% [1].

2.3.3. In-vehicle driver information and navigation systems

In the various in-vehicle information systems applications, the traffic and parking information via RDS-TMC and Digital audio broadcasting (DAB), as well as dynamic route guidance, systems are included. The functionality of digital short-range communication (DSRC) equipment for traffic and traveller information has now been demonstrated under real-life conditions in several urban areas (e.g. in Amsterdam), while RDS-TMC-based traffic information services are available in most EU Member States since 1999. All EU member countries and several non-members have signed a special protocol for the introduction of RDS-TMC services throughout Europe. In fact the introduction of RDS-TMC broadcasts represents the first large-scale implementation of ITS technologies in Europe, paving the way for progressive deployment along the major routes of the Trans-European Road Network.

2.3.4. Roadside driver information systems

The VMS currently represents the main driver information delivery mechanism based on roadside infrastructure. They now provide dynamic on-trip information in a large number of locations throughout Europe, and their usefulness has been demonstrated in a number of research studies and projects. [25] Guidelines for operating VMS have also been developed. [26]

2.4. Operation and management of freight transport systems

The Freight Transport systems of today although improved a lot from the past decades, are not yet integrated enough to meet European-level requirements. The lack of well structured and organised inter-modal transport chains, the existence of uneconomically organized networks and the multitude of uncoordinated transport operations and diverse unit loads with many empty return runs are examples of the considerable inefficiencies that exist today.

As a result, growth in the demand for inter-modal freight services has levelled out (at about 5–7% of total tonnage) indicating that there are

[24] Based on original work and recommendations by fourth FP projects INFOPOLIS II, and TELSCAN (for the elderly and disabled).

[25] See for example results of EU fourth FP project TABASCO, DG INFSO.

[26] By CEN, TC 278.

potentially major difficulties in encouraging more shippers to use this form of transport. One of the major disincentives for using multi-modal freight transport has been the low service quality offered by some modes of transport within the multi-modal chains, a problem that is not yet solved adequately.

Promoting multi-modal transport has been and is likely to remain in the future, a major policy objective at the level of the EU mainly for reasons of achieving "optimal" use of Transport Infrastructure in order to meet environmental or wider social objectives.

Information Technology is considered a primary "enabling tool" for the safe and efficient operation of Freight Transport systems. A first objective of such applications in the field of Freight Transport has therefore been to promote a framework in the direction of integrating the many valuable, but still separate ICT applications in the freight transport sector and to exploiting the synergies that exist. So far attempts to create ICT networks for multi-modal transport require a critical mass of usage in order to make them of interest to the user and economically viable. It is a common problem that ICT networks have found it difficult to attract enough members to reach this critical mass. Thus, although there is widespread acceptance of the need for more integration, the path, which must be followed, is still obscure.

The overriding objective of ICT applications as well as of the related policies in this field, is therefore to affect a virtuous circle in which freight transport operation will be made to work more efficiently (in all respects), safely, and with more opportunities and incentives for modal co-operation.

The various ICT applications in the field of freight Transport, have focused so far on applications and services designed to support integration and inter-modality in three key areas:

1. freight resource management;
2. terminal and port information and communication systems; and
3. freight and vehicle tracking and tracing and "back-office" logistics.

In the *Freight Resource Management* area ICT tools have been developed to improve the freight logistics chain, the exchange of information and data flows, and the organisation of freight movements. Key applications include intra-company resource management systems, on-line freight information systems for cargo terminals, integrated route planning with mobile communications, centralised route planning, Internet based platforms for information and data exchange, and freight capacity exchange systems. According to the results of some research projects in EU's fourth FP (see [1]) during demonstrations of freight resource management applications, offers to potential clients were generated 30% faster than previously and delays due to mistakes in order processing were cut by 30%.

In the area of *Terminal and port information and communication systems* the applications include: systems to operate and optimise the performance of ports and port terminals (e.g. cargo pre-notification to speed up gate procedures, container identification and location processes, etc), logistics information and communication systems for inter-modal cargo terminals, and data exchange systems (EDI or Internet based) between the users and the operators or the inter-modal transport centres.

By far the most important applications in this area are for Ports in general, or for their specialised terminals (mainly container terminals). A state of the art container terminal management system using smart card technology and a series of Data Base Management and GIS technologies, has been developed for the port of Thessaloniki in Greece, offering both container terminal and freight transport operators a reported time saving of up to 83% [13]. Similar applications by use of radio frequency (RF), tags, and smart cards have been tested in medium-sized port terminals but their wider application hinges on the cost of the tags in relation to their being used may be only once on individual container units. Their main use is for access control and quicker loading procedures.

Finally, as regards *freight and vehicle tracking and tracing and "back-office" logistics* systems, this is the area where most of the current freight transport ICT applications exist [14]. Besides systems for Tracking and Tracing vehicles or load

units, the applications focussed also on ways to control and regulate the status (i.e. position, security, operational conditions and integrity) of goods, loading units and vehicles.

ICT systems are also very well suited for exchanging information on freight transport and improving management. They give greater control than traditional methods involving paper, phone and fax, which they have proved capable of replacing.

What is urgently needed for interoperability and compatibility of systems is the development and wider adoption of a common (freight transport) systems architecture, which will allow a common approach to developing new systems and applications for freight transport. There are very valuable benefits to be gained from system architecture. Key advantages include:

- interoperability of equipment with different infrastructures;
- compatibility and consistency of information delivered to end users through different media;
- better integration and co-ordination of services;
- solutions that meet the wider needs of the community;
- greater choice for users;
- multiple use of data and infrastructure;
- reduced risks for industry by developing products against national and international standards; and
- a wider (world) market offering economies of scale in production.

Towards this end at European level, the CEN TC278/Working Group 2, N124 has been making considerable progress lately.

3. The prospects for the future

3.1. The stages towards the "maturity" of new technology applications

The process through which a novel system or technology catches on and becomes a marketable product, is depicted in Fig. 2.

At the beginning there is (pre-competitive) research and development characteristically mentioned as "Invention" in Fig. 2. This is typically supported by government and in some cases privately (industry) sponsored research.

This phase is followed by a stage of initial commercial growth and diversification in which market systems are developed and promoted towards commercial applications. Concurrently with this phase but as a distinct third phase, and as a "critical mass" of users is achieved, the setting of rules and regulations for the orderly function of the market, takes place. Then as the number of users increases, full market functioning and "liberalisation" is achieved.

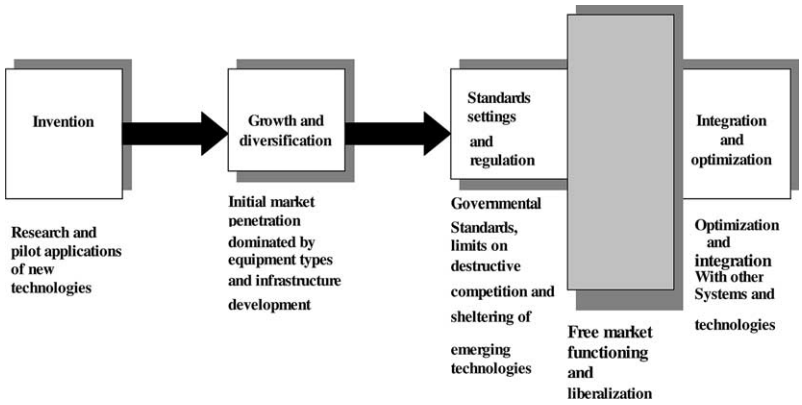

Fig. 2. The process for the development and market penetration of new technologies and systems (adapted from ENO, 1997) [15].

The final stage is the full optimisation and integration of systems and services to achieve highest user satisfaction and acceptance. The whole cycle, from "invention" to full market integration and optimisation, may take anything from 5 to 10 years or more, depending on the type of technology, its cost, market appeal, and other factors.

3.2. The prospects for 2010

It is reasonable to assert that this new decade will be the time when most of the "initial" new technology applications in the transport field, that started their first stages of evolution according to Fig. 2 in the 1990s, will mature and achieve wider market acceptance and integration (i.e. reach the right end of Fig. 2) within this decade.

As a general observation one can note that front-office applications, i.e. the ones that have to do with the management of the (freight transport) functions, will be the ones to reach maturity faster, achieving integrated commercial applications within the first half of the decade.

The same can be said about the applications that are based primarily on Telecommunications and the Internet (e.g. Tracking and Tracing, booking, EDI—mobile or not, etc). Others, that require more substantial (intelligent) infrastructure development, such as automatic vehicle guidance, cruising, intelligent intersection negotiation, mobile traveller information systems, etc may take longer periods to mature, depending on the progress in development and materialisation of the wider Telecommunication and computing "environment" known as the "Ambient Intelligence" (AmI) [27] environment. In a special report [16] on the prospects and potential timing for the materialisation of AmI (always from a European perspective) it was noted that:

> "... *the vision of Ambient Intelligence is a strong starting point for giving direction to research over the coming five years. Major opportunities to create an integrated Ambient Intelligence landscape can be built upon European technological strengths in areas such as mobile communications, portable devices, systems integration, embedded computing and intelligent systems design. A host of new business models will emerge, no matter the response by Europe. But, these new business models will be test-bedded by industry and entrepreneurs operating in the areas that provide the most fertile conditions for experimentation. The vision of Ambient Intelligence points at how to create these fertile conditions, in the technological domain and in the business environment. But all the scenarios also emphasise the social dimension of innovation, the ability as well as the willingness of society to absorb or to react to technological developments. Next to technological and economic feasibility, the implications for issues such as energy, environment, social sustainability, privacy, social robustness and fault tolerance may in the longer run determine the success or failure AmI.*"

The extend and speed with which AmI infrastructure will be materialised will also determine the extend and timing in which the more technologically challenging of the previously mentioned Transport applications will materialise too.

The above passage from the IPTS report on AmI also indicates the particular "social" and "human" dimension that is always present in European technology development research. This dimension is evident in most of novel Transport related applications such as for example the *mobile traveller information systems*. Positive as the current progress and new system applications in this field as they generally are, their wider user acceptance is still subject to question. Translation of current prototype systems into wide-scale deployment on a pan-European or world scale will require evidence of

- efficiency, i.e. a great deal of reliable, rapidly accessible information; a single access point; and the potential to personalise information requests; and

[27] Ambient Intelligence (AmI) stems from the convergence of three key technologies: Ubiquitous Computing, Ubiquitous Communication, and Intelligent User Friendly Interfaces.

- simplicity, i.e. clear content; an understandable interface; and ease of use.

The emergence of the first "generic" so to speak infrastructures, in Transport ICT applications such as personal devices and support tools has enabled already delivery of a range of related applications, resulting in the launch of the first commercial services. These will allow future assessment of the above elements, and hence a more definitive evaluation to be made.

At the moment (and as it looks now for most part of the current decade), there are and will continue to be, clear limitations on the provision of truly multi-modal information, due to current incompatibilities between data sources. This incompatibility will be the main source of difficulties and delays in the further proliferation of truly multi-modal travel or transport systems in the future.

As there are currently no systematic networks for data interchange in transport, this has led to the development of uni-modal or dedicated inter-modal systems. While these may enhance short-term local performance, they can result in substantial duplication of data, discontinuity, incompatibility and inability to exchange data with other current or future partners in the logistics chain. An effective inter-modal information chain capable of serving the needs of both transport users and other participants has yet to be delivered, and it may take the best part of this decade to achieve in commercial practice.

At the same time there is a strong commercial need for future systems and applications to address the whole information chain in an open horizontal framework, instead of through sector-specific sector approach, to ensure commercial viability.

The previous inefficiencies of the existing systems of information provision have their most profound effect in the competitive position and use of new technologies for *small and medium-sized enterprises* (SMEs). The main concern here is the devising and development of mechanisms to bring SMEs into the provision of mainstream information services and applications. This is a very important issue and a stated policy objective of most governments and the EU. Its materialisation, however, can only be seen (by this author at least) through application of innovative business models based on co-operative management of resources and wide use of Internet based technical applications. This will in turn depend on the extent that such (Internet based) applications will achieve user acceptance and economic viability.

The economic viability of new technology systems and applications is another issue that will determine the speed and/or final establishment of new technology applications in the field of Transport. Results of current research studies have shown that it takes a reasonable period of time for such services to become established and economically viable. For example in the area of EDI applications for data and message exchanges in the field of freight Transport a "critical mass" of EDI installations and applications was shown to be necessary before EDI systems became economically attractive especially for the SME users. [28] Also in vehicle control and driver assistance systems, patronage grew steadily once even a pilot application was there—increasing by factors ranging from 4-fold in Uusimaa (Finland) to 10-fold in Campi (Italy). [29] Some limited cases of such services (i.e. of GPS and/or digital mobile data communications) have since been turned into commercial operations, although their economic viability is still partly based not on direct revenues but on savings achieved as a result of their provision [1].

Finally a strong catalyst as regards the number and extend of new technology applications and systems will be the achievement of a commonly accepted system architecture for ITS in Europe. The European Commission strongly supported the development of the European ITS Framework Architecture, through the TAP-Transport KAREN project (fourth FP). Several European countries, including France, Italy and the Netherlands, have subsequently adopted its guidelines as the basis for developing national architectures.

[28] See for example results of third FP project METAFORA.

[29] Such were for example the results of DG INFSO fourth FP project SAMPO/SAMPLUS for the mentioned regions.

Several non-European nations too, including the US, Japan and Australia, have also initiated work on national architectures, and international guidelines are being developed within ISO.

4. Conclusions

This paper is about change in the field of Transport. Change in the way travel demand is formed and generated (or "managed" as the current term goes)—Change in the way travel is planned, and executed—Change in the Transport infrastructures and Networks. The "agent" of this change, which is examined in this paper, is Technology. Technology which is impendent everywhere, "ambient", user friendly, and above all more and more available in every aspect of every day life. We referred to this "technology" by its principal components, i.e. Information and Telecommunication Technologies or ICT.

Many new applications of ICT in the field of Transport are already in various stages of development and/or commercial application. These applications cover all modes of Transport systems, for freight or passengers. The various systems and applications have been reviewed under the headings of the three principal areas of applications as follows:

- Operation and Management of Networks (all modes);
- Information and guidance to the Users (of the Transport systems);
- Operation and Management of Freight Transport systems.

In the operation and management of Transport Networks area, most of the progress was noted in the fields of

1. Traffic Data Information collection and dissemination systems;
2. Network control and traffic management strategies;
3. Vehicle control and driver assistance;
4. Systems for (Electronic or other) fee collection;

In the data and Information transfer field, many new systems are noted in all four modes with similar functionalities. These systems are in their vast majority primarily uni-modal. There is still no progress made towards integrating data and information transfer systems and applications across the various modes. No truly "inter-modal" information systems exist at the moment. However, all experts and policy makers, agree that such "inter-modal" information and data systems would give rise to better and more efficient planning and operation for (end-) users and operators alike.

For information transfer to the end-user (be it a traveller, or the owner of freight) the technologies that are currently and likely to be in every-day commercial practice in this decade are:

- mobile multi-modal travel information devices, e.g. mobile phones, PTAs;
- fixed devices, either Internet based or other e.g. public access terminals (PATs) at strategic locations and interchanges;
- in-vehicle driver information and navigation systems, e.g. via on-board computers; and
- roadside driver information systems, such VMS.

The basic requirement for any successful system of data or information transfer to the users, seems to be:

- efficiency, i.e. reliable, rapidly accessible information; a single access point; and the potential to personalise information requests, and
- simplicity, i.e. clear content; easily understandable interfaces; and ease of use.

In the Network control and management field, systems have been developed and are in the stage of their initial commercial applications. Examples were given and discussed of such systems for road (e.g. the various TICs in several countries), rail (the ERTMS, GSM-R and others), and maritime transport networks (e.g. the many VTS and VTMIS systems being installed around Europe). For air transport, the European GNSS II and the GALILEO satellite navigation and positioning system are the most notable examples but also the

ones the furthest away in time for full commercial application. Applications of these (basically air transport) technologies are being exploited for other modes of Transport (most notably for road and maritime transport).

Intelligent vehicle control and driver assistance applications are also an area with great potential. Several autonomous driving and other vehicle control and driver assistance applications have been successfully demonstrated in the last few years but the application of these systems in every day practice is still many years ahead (and possibly beyond the 2010 horizon) because of the serious safety and other non-technical issues involved such as consumer confidence, system dependability, testing and certification, regulatory implications, liability and other legal aspects.

By contrast the fourth area of transport management systems, i.e. that of electronic fee collection is already in application in many countries for many years now. What should be expected in the next few years (and in any case most likely before 2005) is the establishment of fully interoperable systems of toll and other fee collection throughout Europe, and the application of the technologies that exist today for road pricing schemes and for redesigning the whole system of circulation taxes (for lorries in the first stage).

In the field of freight Transport, the most "immediate" (in the sense of time for maturity) systems and applications concern:

1. freight resource management;
2. terminal and port information and communication systems;
3. freight and vehicle tracking and tracing; and
4. front" or "back-office" logistics systems.

Freight Transport systems of today try to benefit from the various ICT applications but this is done in a fragmented and largely "uni-modal" way. Freight Transport systems are not yet integrated enough to meet European-level requirements and well structured well organised *inter-modal* transport chains do not exist. The development of applications to cover these gaps and inefficiencies in today's systems as well as the integration of Freight Transport within the overall European ITS, will be the challenging areas of research and policy formulation activity for "intelligent" freight transport in Europe in the next few years.

Appendix A. List of abbrevations

AmI	Ambient Intelligence
ADS	Automatic Dependent Surveillance (air transport)
AIS	Automated Identification System
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
CEN	Comittee Europeenne de Normalisation (European Organization for Standards)
CNS	Communications, Navigation, and Surveillance services (air transport)
CTC	Centralised Traffic Control (trains)
DAB	Digital audio broadcasting
DG	Directorate General
DRT	Demand Responsive Transport
DSRC	Dedicated short-range communications
EC	European Commission
ECDIS	Electronic Chart Display and Information systems (maritime transport)
EFC	Electronic fee collection
ERTMS	European Rail Traffic Management System
FP	Framework Programme (of Research)
GNSS	Global Navigation and Satellite System
GPRS	General packet radio services
GPS	Geographic positioning systems
GSM	Global System of Mobile communications
ICT	Information Communication Technologies
IMO	International Maritime Organisation
ITS	Intelligent Transportation Systems
INFSO	Information Society
MTC	Motorway Traffic Control center
PAT	Public Access Terminal
PTA	Personal Traveller Assistant (hand-held devices)
RDS	Radio Data System
SME	Small and medium Sized Enterprise
TCN	Train Communication Network
TEN-T	Trans-European Networks—Transport
TMC	Traffic Message Channel

TREN Transport and Energy
TIC Traffic Information Center
VMS Variable Message Sign
VTMIS Vessel Traffic Management and Information Systems (maritime)
VTS Vessel Traffic Services systems
UTC Urban Traffic Control centre

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