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ORIGINAL PAPER

Towards a European ITS for freight transport and logistics: results of current EU funded research and prospects for the future

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Abstract
Objective The purpose of this paper is to review the developments of the last 15 years in the field of Freight Transport research and innovation, primarily (but not exclusively) in Europe focusing on the "Intelligent Transport Systems" aspects.
Overview In doing so, the paper gives first, a summary of key developments and technologies in ITS related innovation in the freight transport sector over the past 15 years. Then a summary of the main achievements in terms of new technologies that were developed from European (mainly EU funded) research. Finally, the paper discusses the current research gaps and thus priorities for the future, and presents the "main drivers" of innovation in this field.
Results The results of the work are, besides the overall review of the activities and achievements in this field, a novel typology concerning freight ITS, a summary of the most recent technological developments in the field of freight transport, the areas where more work in needed in the future, and finally the priority areas for future research.
Conclusion In conclusion the article stresses the fact that the main challenge in the near future will be to drastically increase the intelligence of freight transport operations, convert raw data to useful information, and how to make it all available to all players irrespective of size. The main areas of application where most of the attention is likely to be directed in the coming years, are:

- ✓ City Logistics;
- ✓ Advanced models and methods to optimize the planning and performance of Freight Transport Operations;
- ✓ Creating the appropriate e-business environment, and
- ✓ Creating the framework for the full exploitation of the capabilities of "intelligent" freight (e-freight).

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1 Introduction

The *Intelligent Transportation Systems*, or *ITS*, is a term generally used to refer to the combined application of *Information and Communication Technologies—ICT,* its related infrastructure, and the necessary legislative / policy framework, in order to optimize transport efficiency and operational sustainability in the future. The term ITS, is equally applicable to the transportation of persons and freight, but within the general ITS framework there are bound to be applications particularly related to one or the other type of transport.

Over the last 15 years, we have witnessed very substantial research and development efforts, as well as investment, aimed at creating and deploying this new generation of transportation systems in order to satisfy a variety of objectives such as control of congestion, increased safety, increased mobility, enhanced productivity and effectiveness of transport system elements, etc. The more "focused" applications for either freight or passenger transport have given rise to the emergence of terms such as *Freight ITS* or *Passenger ITS*.

Freight ITS developments have been up to now largely "technology—driven" with emphasis on the introduction of many sophisticated (although mainly stand-alone) systems and technologies that can collect enormous amounts of data about current status as well as the various planning parameters concerning the operation of freight transportation systems, and to transmit these data in one form or another, to transportation control centers and data bases (impeded in so called "virtual transport platforms") held at authorities, carriers, or various intermediaries. Little progress has been made however towards the achievement of integrated, "holistic", and truly "intelligent" systems providing for the transformation of these "raw" data into useful "information" according to the needs and expectations of each particular kind of "player" along the transport chain, or allowing wider optimization of the chain on the basis of the "total" picture.

So there is a clear scope and benefit in looking strategically to the current status of the ***European Freight ITS*** and the work that needs to be done so that a more balanced and efficiently integrated such *ITS* environment exists, in clear alignment with the transport policy goals set for Europe by the European Commission's transport policy White Paper and its revision. There is also a clear scope in trying to identify and expose the main gaps and weaknesses that exist today in formulating and promoting the future EFITS. In doing exactly this, we will in the following:

1. Make a round-up of key developments and technologies in ITS related innovation in the freight transport sector.
2. Illustrate the achievements of European (EU funded) research in this field so far with appropriate mention of key EU research FP[1] projects;
3. Introduce and use an innovative typology of freight ITS through its various ICT applications; and
4. Discuss the areas where more work in needed in the future (mainly through concerted research and development) in order to improve the performance of European freight transport and logistics systems and contribute towards the ultimate development of the *European Freight ITS*.

2 Key developments to date, and achievements of EU funded research in freight ITS

2.1 The outlook of the last 15 years—key "Technological drivers" developed

The core of ICT applications in freight transport and logistics in the 90s (during the 4th and 5th FPs) as well as the years 2000 (6th and 7th FPs), consisted of systems for obtaining, processing, and distributing information for better use in planning, operation, and management of the freight transportation system, as well as for developing appropriate infrastructures and services.

By the early 2000s the research focused more towards the creation of integrated web based applications able to be shared by many, over the internet.

Original Freight ITS research produced mainly stand-alone applications that can largely be classified in the following two broad areas:

1. *Commercial Operations, i.e.* applications mainly related to the vehicle, the cargo, or the company (operator), and related in their great majority to systems for the better monitoring of the transport (e.g. collection and sending of tracking and tracing data or route choice information, etc).
2. *Fleet Management Systems* i.e. dedicated to the fleet management operations of a particular operator (or group of operators), including transport planning.

Although different in scope, both categories of systems required the development of a number of *enabling technologies* that are largely thought to be the key "technological drivers" for the Freight ITS developments of the future. Some of these are now already firmly established in the market while others are still emerging.

Most of the 1990's technologies enabled therefore, the later more sophisticated activities and system-wide applications as well as the various e-business activities of the firms that form the core of the Freight ITS applications of today. They also prepared the ground for the more wireless, more internet based, and more integrated systems that emerged in this decade and which already point towards the future comprehensive and fully integrated total transport and supply chain management systems of the *EFITS*[2] [8].

Most of the technological drivers in the freight sector[3] were developed in the nineties and early 2000s and were the subject of the original *Freight ITS research* work in the corresponding periods.

It is worth mentioning here the core of these "technological drivers":

- *Mobile transmission technologies* such as GSM, allowing transmission of messages (voice and data) between home-base and vehicles.
- *GPS (Global Positioning System)* technology, enabling for example, Automatic Vehicle Location (AVL) and Computer-Aided Dispatch (CAD) applications.
- Availability of more affordable *positioning information* via these GPS or GSM transmission networks.
- *'Mobile Internet'* made available via wireless broadband communications, for document exchange and access to ICT services (e.g. the navigation services for Personal Digital Assistants—PDAs).

[1] **Framework Programme,** the 5-annual or 7-annual programmes for funding research by the EU. The current programme is the 7th such programme and usually referred to as 7th FP. Equally the previous Programmes are referred to as 6th FP, or 5th FP, and so on.

[2] European Freight ITS.

[3] For a full description see [4]

- The *XML standard*, offering a meta-language for the definition of simple and non-proprietary data exchange standards.
- The various *route guidance and navigation systems* (i.e. packages of algorithms, electronic networks, and software to combine these to useful information assisting the driver in all sorts of ways).[4] The most advanced such systems of today are based on the enabling technologies developed in the nineties and early 2000 and go beyond "canned" information to suggest to the driver "alternative actions" such as for example routes based on actual traffic information.
- *Onboard sensors* performing a variety of functions such as: tracking the vehicle's mechanical condition, monitoring speed, or the state of the loaded goods (e.g. temperature), automatic payment for toll roads, etc.
- Systems and hardware for vehicle or load unit identification. The most notable achievement in this field is the RFiD card (transponder) used as electronic seal or otherwise at terminals, load transfer points, gates of various sorts, etc.
- *Smart cards* enabling new applications such as the electronic tachograph, electronic driver licence, or the storage of load-related information.

The end result and system wide implications of the research and development effort in the last 15 years are now beginning to emerge. They are certainly the basis of new systems and services that are transforming the (European freight transport) industry. Their combination into globally available systems, or their spin-offs that are currently being slowly introduced into the market, are certain to form the backbone of the future European Freight ITS in terms of:

✓ *Availability of integrated information and services*, based on the improved availability of internet standards and infrastructure, for offering web interfaces for tracking and tracing, geographical information and navigation systems, or transport-related data exchanges via XML standards.

✓ *New "Intermediary systems"* offering services such as freight matching, transport auctions, rate quotes or other more specialised functions (for example, the multi-carrier internet portal INTTRA for the shipping industry, or transport exchanges for road transport and air cargo). *Transport exchanges* are third party services offering value-added services to transport providers such as "load matching" services to optimise vehicle utilisation, tracking and tracing, etc. These are not new, as ideas, but their full scale application and trustworthiness are only recently taking a boost due to the previously mentioned "enabling technologies" and their maturing.

✓ *Integrated onboard computer systems and home-base systems* that are interconnected via data links based on GSM/WAP or mobile internet, and offering to the home-base new types of information and data, allowing applications such as emergency re-routing and timely customer/shipper information in the case of delays, or better estimated times of arrival that enable more precise and more efficient resource allocation (e.g. a truck may no longer have to wait long periods at a port because a shipment is delayed).

✓ *New and innovative fleet management and monitoring capabilities* that include in some cases information from floating car data. For example, large companies are now beginning to equip their fleet with sensors transmitting vehicle location to the management centre and allowing new levels of real-time information gathering, flexibility, and responsiveness.

2.2 Freight operations

The Freight Operations area of ITS[5] can be defined as "*Advanced ICT systems aimed at simplifying and automating freight operations at both the operational efficiency level as well as the institutional level*". The goal is to enhance the efficiency of commercial vehicle activities through seamless operations based on electronic vehicle and cargo identification, location and tracking, pre-clearance and in-motion verifications.

These systems relied heavily on *vehicle or cargo positioning systems* (GPS or radio frequency network), *bidirectional communications* (DSRC, radio, satellite, or wireless phone), and *EDI*. In the US initial deployment efforts of CVO technologies have been organized around so-called "corridors". Weight-in-motion scales, overweight detectors, EDI, automatic vehicle (and cargo) identification and classification systems, vision technology (to read license plates), and variable message signs to mention the main technologies used [4].

In the framework of freight Terminals, EDI, GPS, Automatic Identification Systems and similar technologies are heavily tested and developed with significant impact on the performance of transportation systems as a whole and particularly intermodal transportation, and logistic chains. Significant progress has been made in the last decade in introducing automation and advanced information and decision technologies to freight terminals, port container terminals in particular (e.g.,[10, 2]).[6]

[4] Systems such as for example: DynAPS (DaimlerChrysler), AssistPlus (BMW) or Tegaron.

[5] In the US this is more known as *Commercial Vehicle Operations (CVO)*

[6] It must be noted here, that considerable efforts are still being undertaken, in this field, with many innovative projects in Europe and around the world.

In Europe, systems were developed that integrate the basic and enabling technologies (see section above) into data "platforms" for presenting information to both the vehicle and the control center at the office, or even at the roadside. Gradually (starting in the early 2000) all these systems and information combined into internet based "platforms", allow a commercial vehicle to share urgent information with nearby vehicles, and to dialogue with its control center, or with infrastructure operators and service providers. A most notable finding of the research work of the 90s (and of most applications and their Demos) was that there has to be a critical mass of users of ICT applications, i.e. users willing to pay in the market, before a new ICT application can take route and be "attractive" enough, i.e. financially justifiable, to generate more "mass" application [9, 21]. Also that investing in these new systems, may only be profitable when these technologies are fully integrated with other systems within the organization [16].

2.3 Advanced fleet management

Most developments so far in the area of *Fleet Management* (and a significant part of contemplated future applications) address operational issues, load matching and resource allocation, dispatching, and routing, in particular. The principal goal of these systems is to offer the possibility to control and co-ordinate fleet management operations in *real-time* via internet based applications.[7]

In a typical large or medium-sized freight operator, fleet management is a complex task that includes actions and activities that may be known well in advance or that are sometimes repetitive (e.g., vehicles making regular deliveries to food and detail shops), or that may operate in a demand-responsive mode, with the demands for services not always known beforehand, and the fleet has to be deployed and managed (re-routed) in real-time to handle them as effectively as possible.

The focus of *Fleet Management* projects was to produce systems that enable communications between dispatchers in control centers and vehicle operators in the field, and also to ensure timely and correct data delivery to the planning and monitoring systems of the firm The continuous improvement and integration of Global Positioning Systems (GPS) and communication technologies resulted in the improvement in the quality and the reduction in the prices of fleet management systems. This meant wider acceptance of these technologies and their utilization in many modal and inter-modal settings.

The advent of the internet revolution in the late nineties brought new heights in ICT applications in this area all of which gradually became internet (web) based. Further to these, the trend is towards use of ICT and the appropriate planning and operating management methods and instruments, to support **virtual business-to-business communities of interest**.[8]

2.4 Messaging, interoperability, and standardisation developments

Since messaging and data transfer is an integral part of any transport chain, achieving widespread systems interoperability and standardisation has been, and still is, a very important precondition and "enabling" factor for future Freight ITS development. Some segments of the transport industry, especially the SMEs in the road transport, have traditionally been very slow to introduce modern ICT based systems. This is due to the fact that as pointed out before the attainment of tangible benefits requires a "critical mass" of actors using interoperable ICT systems is a necessary precondition for reaping the benefits of these technologies and thus, so far, SMEs have failed to fully benefit from better ICT integration and innovation.

"Messaging" in the B2B context, has until the mid nineties been largely associated with the advent and development of the UN/EDIFACT (*EDI for Administration, Commerce & Transport*) standard which began to be largely used in the mid 80s. The UN/EDIFACT was the only recognised multi-sectorial international standard for message exchange and has been used extensively in Western Europe as a fast and reliable means of achieving electronic, computer-to-computer message exchange between trading partners based on standard messages. Although it is faster, more efficient and more accurate than paper documents, there were several concerns associated with it in the past. For example EDI based electronic documents raised authentication, integrity and confidentiality concerns [15]. The use of digital signatures[9] and digital certificates in fulfilling authentication and identification functions is expected to make electronic documents as legally binding and enforceable as paper documents while encryption can address confidentiality concerns.[10] The above, together with

[7] The **CLISME** project (*Client Service System for SME Intermodal Operator Aug 1999 – July 2001*) was one of the first EU co-funded FP6 projects aiming to improve the competitiveness of intermodal SME operators by utilizing Internet-based information technology. The overall system concept called for a client service application which was developed, programmed, and tested in every day operation with *SeaRail's* customers.

[8] Notable examples are the *European Cooperative Resource Management of Unit Loads* – project *COREM, and* the *Trident - Transport Intermodality Data Sharing and Exchange Network* of ERTICO.

[9] UN/EDIFACT messaging with electronic signature (AUTACK) and encryption (CIPHER) safe X™, the Security Solution Electronic data exchange and security. http://www.edisol.win-uk.net/SafeX.htm

[10] See also: http://www.ecomm-debate.co.za/greenpaper/academics/pistorious2.html

the inherent complexity and special effort required in "creating" appropriate EDI messages led to the gradual reduction in EDI applications[11] in favour of more simplified and internet based messaging technologies namely the XML.

The use of the Internet for trade facilitation became the catalyst that led to the replacement of EDI in the medium term. An important facilitating role was played by the rapid rise of the **XML** (*eXtensible Markup Language*) standard as a means to encode semantic structures pertinent to a domain in a form, which is both machine-readable (well formed) and human-readable (marked up with meaningful tags). XML has become today the most important data interchange format for e-business. An XML document can be displayed by software (for example, by a standard Internet browser) but it can also be processed by domain-specific applications in the same way as EDIFACT messages. There are now conversion tools such as the XML-Edifact[12] which offer an open path for migration between XML and UN/EDIFACT, turning the complex EDIFACT messages into a human-readable format.

XML has become the basis for the definition of new protocols for platform-neutral interoperability such as the widely supported ***SOAP*** *(Simple Object Access Protocol*)[13] that allows remote procedure calls between applications in a distributed environment. Another originally competing standard, the ***ebXML***, that grew out of UN/CEFACT[14] and OASIS[15] and also supports more complex aspects such as digital signatures and no-repudiation, will integrate SOAP into its *Messaging Services Specification*.[16] The XML technology seems to be cheaper and more flexible and is generally present in most software applications. Its wide availability and ease of use will allow the wider transport related community to communicate with each other—particularly those for whom EDI-type applications are beyond reach.

The proliferation of XML-based business interchanges has served as the catalyst for defining a new global paradigm that is currently on the rise, i.e. that all business activities, regardless of size, could engage in "e-business" activities.

A most well known "spin-off" of XML, known as **ebXML**, has recently (2001) been developed by an international initiative established by the *United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT*)[17] and the *Organization for the Advancement of Structured Information Standards (OASIS)*. It enables enterprises to conduct business over the Internet in more straightforward and efficient ways than in the past. The *ebXML* has been standardized and it is currently known also as ISO 15000.

3 A typology of freight ICT applications and systems

In order to present better the progress made so far on ITS for freight, it is useful to examine the various developments into six broad categories using as criterion their focus or area of applicability. Such typology could also help in evaluating the trends and future needs.

A. E-Business-oriented systems

Notwithstanding the current[18] volatility of the stock exchange and the foreseen severe economic downturn, the development and full utilization trends for *e-business* applications, that started in the early 2000's, is still clear and strong. Significant opportunities exist for transportation firms, as for other economic agents, in terms of larger and stronger business partnerships, more streamlined, rapid, and demand-responsive decision processes, improved operations and service levels, enhanced customer satisfaction and, ultimately, profitability.

To reap the benefits of these opportunities, freight transportation agents (carriers, logistic service providers, and so on) take advantage of the convergence between ICT and e-business technologies. This entails full exploitation of the potential of Internet-based operations, and electronic commerce mainly in order to realize applications in the business-to-consumer and business-to-business sides of the freight transport operation and logistics.

Enabling technologies such as *information and decision support technologies, two-way communications, electronic data interchange, computing and data handling technologies, advanced planning and operation decision support systems* and all the so called *E-logistics* applications aimed at planning, managing, and controlling the efficient movement

[11] For example as late as 1998, less than half of the European port communities included in a COST 330 study [3] used EDI/EDIFACT. The same COST study predicted that figures (of EDI users) would not rise significantly since the benefit of using EDI was not well understood or accepted and the EDIFACT messages were perceived as being too complex.

[12] XML-EDIFACT. http://www.xml-edifact.org/

[13] SOAP for Platform-Neutral Interoperability in http://www.xmlmag.com/upload/free/features/xml/2000/04fal00/kb0004/kb0004.asp

[14] UN/CEFACT is the United Nations body whose mandate covers worldwide policy and technical development in the area of trade facilitation and electronic business. See http://www.uncefact.org/

[15] OASIS (*Organization for the Advancement of Structured Information Standards)* is an international, not-for-profit consortium that advances electronic business by promoting open, collaborative development of interoperability specifications. http://www.oasis-open.org

[16] ebXML Integrated SOAP into Messaging Services Specification (2001) http://www.ebxml.org/news/pr_20010222.htm

[17] www.uncefact.org

[18] End of 2008.

of goods, information and money, are being researched and demonstrated as part of the on-going ICT research efforts.

As a result of the above developments we gradually see the emergence of *Internet-based communities of interests* and *electronic auction mechanisms*. The virtual market places that implement freight exchanges offer carriers the perspective of an easier access to loads and smoother operations. This is certainly true for full-load carriers, but it also presents significant opportunities for consolidation-type companies, LTL motor carriers in particular. The loads that could be obtained by accessing these markets would reduce the need to move empty vehicles to balance the operations. Such markets complement the more traditional auctions of distribution routes of major industrial or retail firms [13].

The e-Business-oriented and customer-focused ICT systems are the latest historically, and owe their existence to a large extent in the growing popularity and ubiquity of the Internet that has now taken over from EDI as the dominant platform for electronic business. They are Internet-based transport exchanges implementing a variety of business models (from mere brokerage to full transport responsibility) and sometimes including various interfaces (web/internet, mobile phone/handheld, roadside kiosks, etc).

In the same category the so called "*customer-focused*" ICT systems can also be included. These systems help shippers find appropriate transport connections and modes, simplify transport-related tasks (such as getting quotes or comparing prices across diverse operators and modes) or, during transport, track bookings and shipments. Many functions are now offered by independent service providers taking responsibility for shippers' transport needs under specific service level agreements. Many shippers are now outsourcing parts or all of their logistics operations to 3PL (third party logistics) providers. There are also service providers for a range of ancillary transport functions such as customs brokerage, insurance or warehousing.

B. Freight Operation (proprietary systems)

These systems are the traditional logistics systems operating on the level of one large and usually globally operating forwarder or integrator. They can cover a wide range of functions such as resource allocation / fleet management (load units, schedules, transport services), consolidation and sorting of shipments, positioning and navigation, automatic vehicle or load unit identification via RF tags, barcodes, or freight management functions including re-routing and re-scheduling.

Freight transport operators have their own proprietary logistics systems for the various transport functions, before, during and after transport:

- *before transport* (route planning, resource allocation, or documentation for customs clearance or dangerous goods information)
- *during transport* (tracking and tracing of shipments and bookings, delay and problems, notification of changes to ETA)
- *after transport* (proof of delivery, administration and financial clearing, benchmarking and statistics).

In general, such systems may be divided into ***onboard systems*** and ***home-base systems***. To the extent that these systems are integrated this distinction will become increasingly blurred.

Onboard ICT systems fulfil a variety of functions:

- collect information about the vehicle or the load, e.g. temperature of cargo, engine parameters, fuel consumption, or safety-related aspects (electronic tachograph)
- relate the vehicle to the environment, e.g. establish location information via GSM and interface to external navigation services, offer, via technologies such as voice, SMS, WAP or others, means of communication to the home-base, other actors such as customers or other drivers or information services (e.g. providing up-to-date routing information)
- link the vehicle to the home-base (see below)
- Fulfil the functions of a mobile office, e.g. send out quotes, confirm bookings or delivery, send electronic documents via EDIFACT or XML standards, and communicate with shipper or other actors via voice, email, SMS etc.

Home-base systems cover functions such as:

- route planning, possibly making use of pertinent and current (emergent) traffic information
- fleet management
- communication to vehicles: send information regarding delays or changes, instructions for re-routing or additional transport tasks, or transmit electronic documents
- communication from vehicle: receive vehicle parameters such as position, speed, load or vehicle status to be fed into the transport management system;

Home-base systems can use vehicle data to improve fleet utilisation, inform operational planning, or aggregate statistical data for strategic planning. They may also support the marketing of certain types of data, such as floating car data to Travel Information Centres or Navigation System Providers.

C. Intermodal Transport operating systems (spanning over a number of modes and actors)

Intermodality has been the subject of intense research efforts during the last decade. The subject matter of this research is innovative technological concepts including hardware and software for door-to-door transport chain monitoring and supply chain management. It also includes systems that try to provide "intermodal" information on schedules and services using common definitions and solutions for the interoperable and seamless data exchange between all the parties in the intermodal chain irrespective of the technologies they are using for data capture. Also proprietary logistics systems that aim at integrating subcontractors and fulfilling functions such as messaging and financial clearing also belong here.

This is a huge area of applications that has been given intense attention in the Policy and Research documents of both the EU and the Member states (National Governments).

Early research in this area produced concepts of "*intermodal transport platforms*" i.e. centrally planned or distributed data and information sharing platforms such as the *Intermodal transport chain management system (TCMS)* of project **INFOLOG**,[19] or the **GIFTS** project's "V*irtual terminal integrated platform*",[20] the project's **D2D** platform,[21] etc. The initial GIFTS proposed platform is reprinted here (see Fig. 1 below).

The most recent and advanced such development at the time of writing this paper is the integrated intermodal platform developed within the **SMART-CM** project for the door-to-door monitoring of containers around their global movement, and providing data and information to:

a. The customs for reliable free, secure, and above all "technology neutral" information that will allow the uninterrupted flow through customs checks, and
b. The logistics players around the whole chain for reliable and state-of-the-art applications that will enhance the efficiency of the chain (the so called value-adding services–VOS).

- **The SMART-CM intermodal container transport platform is shown in *Information gateway:*** *Container status information entry point from a variety of available sources, (container security devices/e-seals, other RFID infrastructure, as well as sources such as Port MIS or fleet management systems).*
- ***Visibility (infrastructure):*** *Utilizing web-based mapping software to provide a centralized tool for the visualization of information of interest to logistics operators.*
- ***Value added services:*** *Exploiting the information provided by the Information Gateway and the Visibility Layer, to provide additional functionality of interest to the industrial partners.*
- ***Neutral visibility:*** *The part of the platform that authenticates and provides the "neutral" data for use by customs.*

Figure 2 below.

The systems that support the so called "*network operators*", that operate systems for data collection (positioning, etc) that employ roadside or rail side tags to measure traffic flows or provide vehicle or rolling stock positioning information, also belong in this category.

Finally, due mention is necessary to the work that has been directed towards creating efficient algorithms for the optimization of decision making, scheduling and dynamic re-scheduling along the door-to-door transport or supply chains of the future.

D. Site-specific ICT systems

Such systems are usually operated at specific sites such as ports and Terminals, Terminal gates, Freight distribution centres, border crossings, etc. One of the pioneers in this field was project INTERPORT[22] which introduced the integrated port management system concept that has later been developed to a fully integrated Freight Transport Chain Management system called ***FRETIS*** that is now commercially available in Europe.[23]

Possible functions of specific-site ICT systems are:

- *Terminal management*,
- *automatic vehicle* or *driver identification systems*,
- *warehouse operation* and *management,*
- *planning functions*,
- *Loading / unloading operations*, etc.

Site-specific ICT systems can link technologies such as freight scanning (usually barcodes) with other transport

[19] See http://www.tfk-hamburg.com/infolog

[20] The GIFTS (Global Intermodal Freight Transport System) project (September 2001 – August 2004) aimed at setting up, and operating a Global Freight Information System - GIFTS, aimed particularly for Intermodal Transport, and based on a Global ICT data infrastructure for the various freight transport services that the users will need, to be fully integrated within the future European ITS (Intelligent Transport System).

[21] The D2D project (Demonstration of an integrated management and communication system for door-to-door intermodal freight transport operations, May 2002 – February 2005) aimed at demonstrating how to efficiently organize and manage intermodal door-to-door transport chains, in which shipping plays a major role. The approach of the project was to use logistics management and data communication systems by use of ICT. The project produced one of the first integrated transport chain management software and system architecture.

[22] Project **INTERPORT** (*Integrating Water Transport in the Logistics Chain, Jan 1996 – Jan 1999, FP5*) was one of the pioneering projects of FP5 in the field of Freight Transport dealing with port terminals operation to ensure efficient handling of cargo and the related information.

[23] For information on **FRETIS** see its developer and promoter TREDIT SA: http://www.tredit.gr. The Container Terminal management module of the FRETIS system (called FRETIS/IFT for *Intermodal Freight Terminal*) is the system that operates the Container Terminal of the port of Thessaloniki in Greece (annual throughput approximately 500 000 TEUs, forecasted to increase to 1.5 million by 2015) for more than 4 years now.

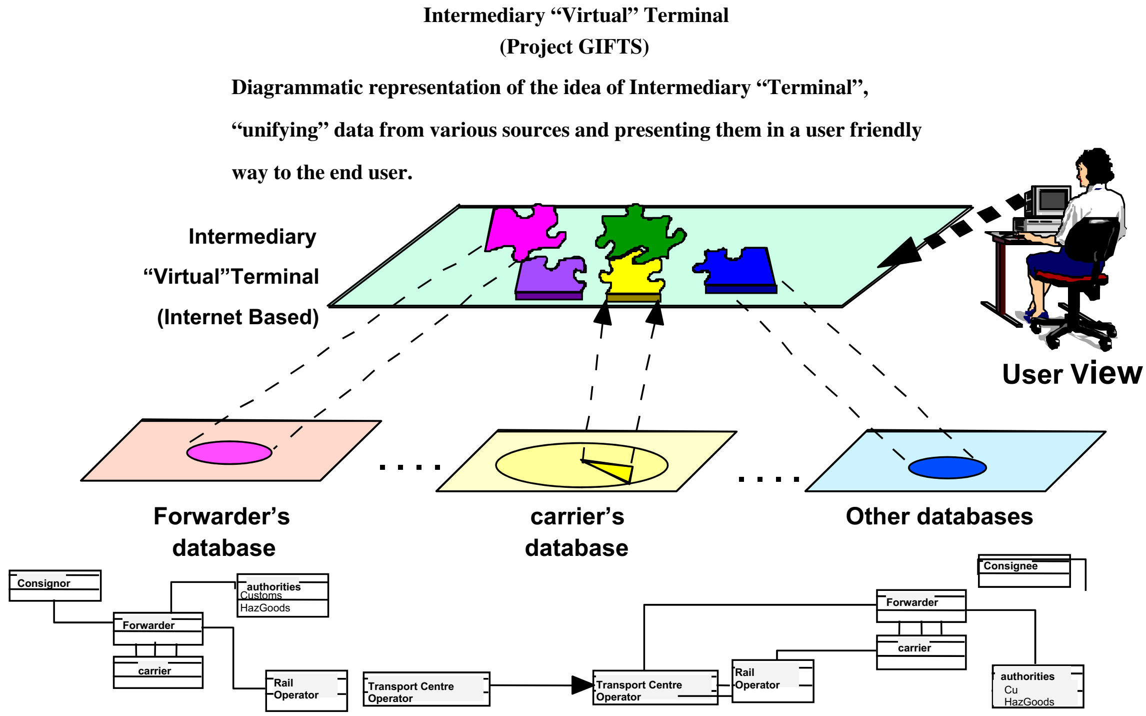
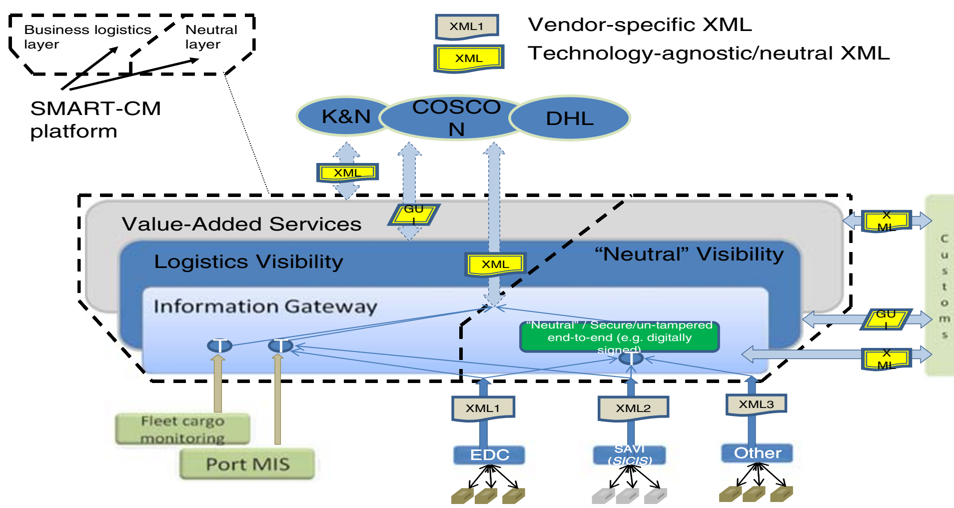


Fig. 1 One of the first examples of an intermodal Transport Management Platform concept (Source: project GIFTS [11])

Fig. 2 The SMART-CM intermodal container transport monitoring and data handling platform (source: Project SMART-CM [18])



- ***Information gateway:*** *Container status information entry point from a variety of available sources, (container security devices/e-seals, other RFID infrastructure, as well as sources such as Port MIS or fleet management systems).*
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related tasks such as sorting, inventory systems, or invoicing and deduction.

For transports involving several modes and actors, the main challenge remains to provide to all actors current information about schedules, as well as for the status of the shipment and the entire transport process. Often, specific information (such as shipment location) exists, but it may be contained in proprietary systems, which do not conform to data exchange standards. The ultimate trend (most notably addressed by the e-freight developments is that shipment information must move from the level of the *transport means* (e.g. ship, or train, or container) to that of *load unit* (wagon, box) or even *individual item*.

E. Transport and other Public Administrations related systems

This area includes systems that implement safety, security or revenue mechanisms and are run by public, or private, administrations such as customs or port authorities. They may also be outsourced to private operators or PPPs (Public-Private-Partnerships). Examples are systems for dangerous goods declaration or customs clearance systems, electronic fee collection systems for toll roads, smart card based functions such as the electronic tachograph, etc.

Customs clearance systems are increasingly geared to interface with freight operators and thus novel applications are almost continuously appearing (e.g. the ACCS system at Hongkong's Chek Lap Kok Airport). Traffic information services offered via public bodies or private public partnerships (such as the Verkehrsmanagementzentrale in Berlin[24]) also belong here to the extent that they contribute data that can be used by freight transport management.

In the aviation sector, several initiatives are in place to connect with the other modes, and are probably ahead of their time. For example, the *CDM (Collaborative Decision-Making)* system approach aims at pooling flight data and make them available also to air cargo operators as well as operators in other transport modes connecting to air transport.

Security policies are a very important element in this category. They significantly increase delays at ports and border crossings and thus are of increased interest for research and development as they influence the efficiency of commerce and supply chains. For example, the U.S. *Customs Container Security Initiative*[25] requires the inspection and pre-clearance of a certain proportion of containers **before** they leave the port of origin or the last major transshipment port. The U.S. Customs and Border Protection agency requires advanced transmission of cargo information for shipments destined for the United States. This influences freight transport all over the world. Systems are being deployed to mitigate the associated significantly longer delays. For instance, U.S. and Canadian customs commercial programs are being aligned (e.g. the *Free and Secure Trade*, *FAST*, program) to support moving pre-approved goods quickly across the border [14]. The program is based on registering and pre-approving import/export firms (shippers), carriers, and drivers.

F. City logistics

City Logistics is a whole area of work and development that is investigating urban freight and logistics components of an integrated urban logistics system aiming to optimize the entire system accordingly. Coordination and consolidation are at the basis of the urban logistics optimization idea: Coordination of shippers and carriers and consolidation of different shipments of various shippers, carriers, and customers by the same (energy efficient and environmentally friendly) vehicle.

The concept of a *City Distribution Center* has been developed as instrumental in most City Logistics proposals and developments. A city distribution center is a facility where shipments are consolidated prior to distribution. It is noteworthy that the concept of city distribution center as physical facility is close to that of intermodal *logistic platforms* (and *freight villages*) that link the city to the region, country, and the world.

Most city-distribution-center projects involve only one such facility and a limited number of shippers and carriers. Different strategies have been tested.[26] The "*City Logistik*" concept developed in Germany corresponds to "spontaneous" groupings of carriers for coordination and consolidation activities, is a notable European example.

G. E- Freight

This is a novel area with great potential in the future. It includes concepts, technological solutions and business models to establish ICT applications based on the context of **individual cargo** items and their interaction with the surrounding environment and the types of users. The idea is that *e-freight* will support 'on the fly' combination of services between user, context and cargo, improving and integrating a number of advanced technologies, including: Service-oriented architectures incorporating mobile technologies, interoperability between heterogeneous environments and advanced security features, semantic web and domain

[24] Verkehrsmanagementzentrale Berlin. http://www.vmzberlin.de/

[25] www.customs.ustreas.gov/xp/cgov/home.html U.S. Customs and Border Protection, Department of Homeland Security

[26] The main European experience in this field can be found in the work of the BESTUFS (*Best Urban Freight Solutions*) consortium and project at www.bestufs.net. Project **BESTUFS** (I AND II) was a coordinated action project that investigated possible organizational, technological, ICT, legal, policy aspects of urban freight delivery and logistics. Its compendium of solutions, best practices, and possible systems for application are a unique source of information on this domain. Other information can be found also in www.transports-marchandises-en-ville.org and in: [7, 12, 19, 20], etc.

ontologies for automated discovery of services associated to any specific cargo item; advanced context technologies, for combination of items, vehicle and user IDs with automatically detected conditions like, e.g., position and status of cargo; distributed intelligent agents, for optimization, anomaly and threat detection (alerting); decisions support tools, etc.

Such developments will simultaneously improve the logistics, business processes and public policy aspects of freight transportation, by dynamically combining services at different levels, i.e. at the:

- ✓ Micro level, i.e. the immediate proximity of a RFID tagged cargo item;
- ✓ Producer, Shipper, and Carrier Supply chain level including qualification, handling and routing;
- ✓ Freight corridor level, represented by authority and infrastructure services including authorization, security and safety control.

4 Future needs and prospects

4.1 The general outlook

The "current" era of Freight ITS research is marked by the publication of the 2006 revision of the White paper on Transport policy of 2001, and the Lisbon and the Barcelona declarations[27] that led to the creation of the European Research Area. The new systems for the coming decade and beyond will be characterized by the four "***I***"s i.e.: ***Integrated***, ***Intermodal***, ***Internet*** based, and ***Intelligent.*** These will be the ingredients of the truly *Freight Intelligent Transport System (Freight ITS)* of the future and will hopefully materialize the vision of a globally integrated framework for freight movement realizing a synergy between the various previously isolated systems.

Research & development will continue to progress along three major, parallel but complementary, directions:

a) ICT for vehicular and infrastructure intelligence.
b) New hardware and software systems for advanced integrated electronics, location, tracking, and communication, as well as the associated information-technology systems.
c) New intelligent models and algorithms to process the data and information gathered with the systems developed so far, and transform this information into timely and meaningful advice for advanced system and fleet planning, management, operations and control.

In a sense, we are now faced with similar challenges to the ones that led to the initial development of Freight ICT research—in the mid-nineties, i.e. innovative hardware that is being developed and deployed, but which still remains to be inserted in a truly integrated and efficient Freight ICT system architecture. Transport supply chains and logistical processes in trade and commerce (e.g. inventory reduction through "Just-in-Time", procurement practices, just-in-time replenishments of goods in the retail industry, etc) will continue to require novel and innovative ways to employ ICT. The main challenge will be to drastically increase the **intelligence of freight transport operations** and make it available to all players in the field irrespective of their size**.** As a first step research should focus on questions such as these posed at the beginning, i.e.:

- Are all of the data collected, transformed into *useful information*?
- Is this information *properly (i.e. intelligently) exploited*?

Answering these questions will involve combining basic logistics and freight transport knowledge e.g. for planning and scheduling activities for an overall Freight ITS management framework, with the capabilities made available to us by the electronics and telecommunication systems developed with ICT research. These issues are not yet sufficiently addressed and research and development efforts are likely to continue to be undertaken in these areas in the future.

Other areas of work that is still needed, relate to:

- ✓ Real-time allocation of resources, decision making, and management of operations, including real-time fleet management and vehicle re-routing (urban or interurban). Also real-time decision support systems that take into account congestion and dynamic demand conditions, or that coordinate with the decisions of other agents (e.g., Customs or port operations).
- ✓ Planning and management of integrated logistics networks (chains) and the links to ITS, Advanced Fleet Management Systems (real-time management in particular).
- ✓ Trade-offs between accuracy of results and response time in real-time settings.
- ✓ Development of the next generation of planning models and methods for carrier or shipper operations that integrate the stochastic and dynamic aspects of ITS. Similarly, development of the next generation of urban/regional planning systems that reflect the utilization of CVO and AFMS technologies.
- ✓ New intelligence systems that allow the combination of central processing and the computing power of onboard computers and the next generation of transponder devices

[27] The Lisbon Agenda of March 2000 had the vision of transforming Europe to a knowledge society through a European Research and Innovation Area. Two years later, the Barcelona Agenda set a target for Europe of a 3 % GDP expenses for Research and Development activities including roughly 2/3 from private funding and 1/3 from public funding.

in order to produce new tools for dynamic scheduling and re-scheduling of vehicles and operations.

City Logistics—the integrated management of freight movements within urban areas—constitutes a fascinating and quite promising research domain (relatively young too!). Research is still required on the technical, design, operational, management, policy, etc., aspects of City Logistics. Operations research models and methods are needed to assist the design, evaluation, planning, and real-time management of operations of City Logistics systems. Many research directions must be explored related to the city logistics ideas. Other than the technical aspects, one needs to focus on the organizational and managerial framework of such systems. The involvement of the local and central governments must be clarified. New business models are also required.

Advanced models and methods are needed to decide the design and optimization of City Logistics systems. Challenging issues include the location, layout, and operation of the distribution centers a well as of the entire City Logistics network and services, the planning and scheduling of services, and the real-time operations. In fact, all the decision issues associated with the design and operations of an advanced transportation system must be addressed within the City Logistics framework.

Another area of future work is the further enhancement of the **e-business** environment of Freight transport. The emergence and rapid growth of electronic business practices both challenges and offers freight carriers with great opportunities for improved operations and profits especially in the intermodal domain. The convergence of information, communication, and decision making technologies used in CVO and AFMS[28] constitutes a significant advantage in this context. Significant research is still required in this area, and in particular in the area of the so called *combinatorial auctions*[29] and the development of efficient and comprehensive "advisors".

1) Three particularly challenging aspects of this issue are the: New modeling capabilities (with stochastic and dynamic formulations);
2) Development of methodologies to address the contingency issues when bundles have to be negotiated in parallel or non-combinatorial markets;
3) Determination of bidding strategies (e.g., estimation of probabilities of winning, of competitor behaviour price and bid modification, etc.) in various settings, parallel and continuous markets in particular.

Another major item for future research needs to address the trend towards outsourcing in the transportation sector. This trend means that there is a strong demand for better integration of transport management information. Often, the actual transport provider is a small company not having the resources and technical means to link into forwarder's IT systems. The position of a shipment may therefore not be known on the legs of the trip that are outsourced.

The Internet-based electronic business which is now strongly contributing to the transformation of the freight transportation industry needs to go all the way to the SMEs in the freight transport sector. The main external factors driving this transformation are the modifications to the logistic chains and practices of major industries and economic sectors, the proliferation of electronic spaces (websites) where shippers and carriers may meet and close deals, and the continuously increasing volume of individual consumer ecommerce activities.

There are also increased requirements for research in new or improved freight transportation services in terms of:

- enhanced customer value,
- reduction of transportation and distribution costs,
- delivery time reliability
- Compliance with the security requirements.

A note is finally necessary here about the on-going recent economic crisis situation and the volatility of the stock markets around the world which are clearly going to have long term impacts on the freight transport industry too. These impacts include restructuring pressures, reduction in demand for services (including ITS based), reduction in investment, and above all loss of interest in spending for new systems perceived as "future fancies". However, the current economic crisis could indeed be an opportunity as it may induce a more innovative approach to decision making and thus spur government support for innovative concepts and technologies. This is already the case with the recent (26th November, 2008) European Commission's directive on the measures to combat the economic crisis. The Commission's position included a major reference to actions designed to support innovation and especially the so called *Green Car initiative* i.e. the development of the next generation "clean" cars of the future (electric cars). Also the economic crisis can be an

[28] Commercial Vehicle Operations and Advanced Fleet Management Services.

[29] Auctions in which participants are allowed to bid directly on attractive "bundles". Being able to bid on "bundles" clearly mitigates the *exposure problem*, which arises when one gains too few or too many of the items desired, since it gives the participants the option to bid their precise valuations for any collection of items they desire. On the other hand, combinatorial auctions require more complex operations research mechanisms to determine load allocations and the corresponding prices [1, 4, 17]. Significant research is currently dedicated to combinatorial auction mechanism design issues, as well as to the associated operations research and combinatorial optimization methodologies. These efforts have already resulted in the successful utilization of *combinatorial auctions* in many applications.

"opportunity" through the expected re-organisation of the existing logistics networks to respond better to the trends for larger and stronger business partnerships, more streamlined, rapid, and demand-responsive decision processes, improved operations and service levels, enhanced customer satisfaction and other requirements which now take on a new perspective and urgency.

4.2 The need to create a common ITS based freight architecture and reference model

The main issue in creating a common *Architecture for ITS based Freight and Logistics* operations would be the adoption of a common reference framework (including concepts and notions, common messages, data formats, and processes) that would comprehensively cover all elements and stages of an intermodal transport chain.

Formulation and adoption of such "Architecture" is a necessary precondition for the establishment of the future EFITS. It should extend to all elements of the system from load units and types of cargo, to actors, interchange terminals, transport services, schedules, messages and documents. It would also serve as a reference point for transport management system development, making available generic data models, process specifications and message schemes.

The most notable and recent attempt towards formulating such Architecture is the work that is being done within the EU funded project **FREIGHTWISE**[30] which aims to produce a standardized reference model for intermodal freight transport operation in terms of standardized roles, functions, processes and messages. The project also intends to integrate and demonstrate practical ICT solutions to the stakeholders in order to enhance the use of ICT in intermodal transport and thus make it more competitive, and in line with the European Commission's policies and directives in this area.

4.3 The need to integrate freight transport operation within the modes and with the respective traffic management systems

In any future ITS a major requirement is the accurate, intelligent and timely information provision from the traffic management systems on the various networks (all modes) to the freight transport management and operation centres operated by the transport providers (freight transport operators). This is necessary in order to optimise the on-line dynamic routing and scheduling capabilities offered by modern ITS and in order to provide valuable data for the trip planning and fleet management tasks. As an example, in the case of road traffic management centers, the freight transport management sector could profit tremendously by provision of information such as:

- ✓ Traffic conditions, closures of streets, traffic restrictions, etc;
- ✓ Waiting hours at specific congestion "hotspots" such as entry to ports, or railways, or borders to third countries ;
- ✓ Schedules of ferry links;
- ✓ Parking areas and service stations for freight transport;
- ✓ The height of bridges (services are being developed);
- ✓ Permits for freight transport;
- ✓ Freight transport related associations;
- ✓ General information on ports;
- ✓ Customs location, opening hours, etc (mainly in the port or freight centers)
- ✓ Terminals (locations, etc).

The issue of "linking" transport to traffic management across modes and systems was first pointed out as being of paramount importance almost ten years ago by a research project called **THEMIS**.[31] The same project specified that such "linking" should form a major task and element in any future ITS. The drawing in Fig. 3 shows this in a diagrammatic form. The idea is to develop systems and hardware that will enable the (ideally automatic) connection between freight and fleet management with data and information from the corresponding traffic management systems for the networks used.

So far little has been done to achieve this goal in its true and total sense of Fig. 3 except perhaps the freight transport management centres, for firms operating in the area, in the Verkehrsmanagementzentrale system in Berlin.[32]

The existing *Traffic Information Centers (TICs)* can be regarded to provide the appropriate basis for freight transport relevant data and information but so far, very little specific data is processed and provided to the freight transport planning or monitoring activities. Reasons are:

- Public authorities (as far as they operate TICs) do not have in mind the actors of the private freight transport sector but mainly the general traffic and traffic safety related aspects of ITS.

[30] *Freight management framework for intelligent intermodal transport* - 6th FP funded research project that started in October 2006 and is scheduled to end April 2010.

[31] THEMIS project "Assessment of the Freight Functional Framework and the feasibility of business cases", EU funded project under the 5th FP, http://hermes.civil.auth.gr/themis/assets/library/pdf/Task%203-4.pdf (2002):

[32] Verkehrsmanagementzentrale Berlin. http://www.vmzberlin.de/

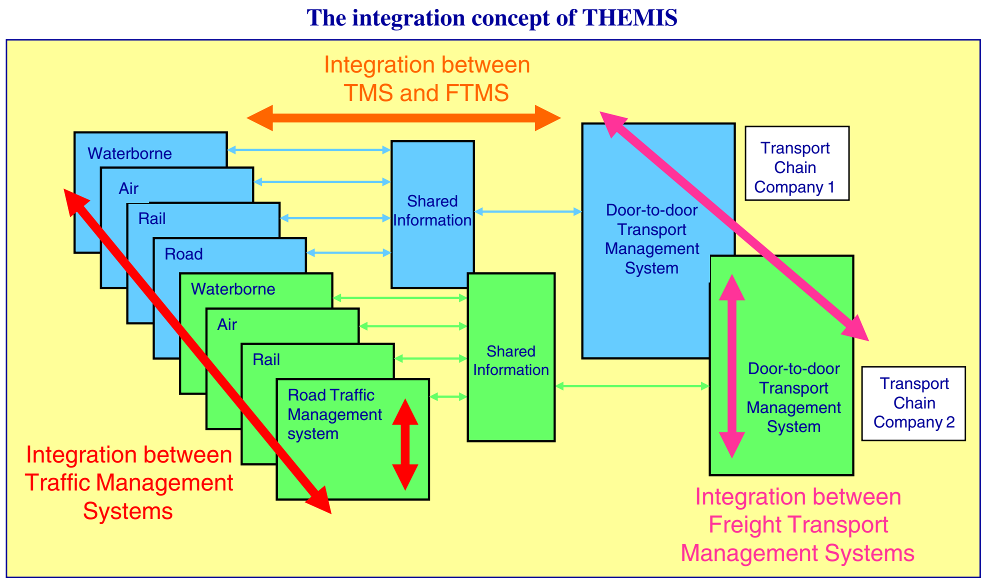

Fig. 3 Diagrammatic representation of the need to integrate Freight Transport Management systems along the modes and across to the corresponding traffic management systems (taken from the original Diagramme of project THEMIS)

– Private bodies (as far as they operate TICs) do not "care" much about the (private) freight transport sector as long as they do not identify willingness to pay for the information provided.
– The freight transport market—compared with the private car market—is relatively small.

4.4 The need for systematic data analysis and modeling for freight transport

Data analysis and development of planning models have been a (relatively speaking) "poor relative" of the EU funded freight transport research. Europe-wide data for modeling freight transport operations are scarce and their use for planning or operational purposes rather limited. Contrary to what happened in the US [5], European modeling and simulation for freight transport operations and transport in Europe have still to be developed at a Europe-wide and common approach basis.

Dynamic traffic simulation offers another tool to studying freight transport operations. Simulation offers the tools to explore and validate operating strategies and appears as part of the core methodology for predicting travel times for Advanced Fleet Management and Travel Information systems. Its main role in actual real-time dispatching and routing of vehicles has to do with the fact that it is the necessary basis for a number of methodologies and decision support systems that can assist the planning and operations manager of freight carriers to optimize his / her operations [6]. Today almost all of these systems are based on static formulations using the carrier's own historic data and forecasts based on them.

Certainly, the advent of ICT based location and communication technologies offers the possibility to enhance the quantity and quality of the data available for the forecast and planning processes.[33]

5 Conclusions

There is no doubt that EU funded research over the last 2 decades has been an extraordinary "force" behind the current developments in Intelligent Transport Systems for Freight and Logistics. Most of the systems and applications in use today have been originally conceived in EU funded research projects that run through the nineties and 2000s.

A number of technologies have been developed and are now commercially available that are changing the face of Freight Transport. Such technologies include:

- *Mobile transmission technologies* such as GSM.
- *GPS (Global Positioning System)* technologies (for Automatic Vehicle Location and Computer-Aided Dispatch applications).
- *'Mobile Internet'* via wireless broadband communications.
- The *XML standard*, offering a meta-language for the definition of simple and non-proprietary data exchange standards.
- The various *route guidance and navigation systems.*

[33] The most representative European work in this area is the ETIS reference database. ETIS has been developed by the EU Commission in close cooperation with EUROSTAT in order to provide the Commission with a policy oriented information system. In connection to the ETIS database the WORLDNET project (*European transport network model refinement regarding freight and intermodal transport to and from the rest of the world*, May 2007–Feb 2009, a project within FP6/Policies) is an example of a project aimed at Transport Policy implementation and assessment using a "model", the so called TRANS-TOOLS model.

- *Onboard sensors* performing a variety of functions.
- Systems and hardware for vehicle or load unit identification.
- *Smart cards* for electronic tachographs, electronic driver licence, or storage of load-related information.

The combination of these (and more) technologies into globally available systems are now beginning to form the backbone of the *European Freight ITS* of the future. There is for example today:

✓ *Increased availability of integrated information and services* (based on improved internet standards and infrastructure, web interfaces for tracking and tracing, geographical information and navigation systems, or transport-related data exchanges via XML or other standards).

✓ New and more advanced *"Intermediary systems"* developed for services such as *freight matching, transport auctions, rate quotes* or other more specialised functions.

✓ More versatile and user friendly *integrated onboard computer systems* as well as *home-base systems* that are interconnected via data links (based on GSM/WAP or mobile internet).

✓ New and innovative *fleet management and monitoring capabilities* that include in some cases information from floating car data.

The systems and services that have been developed over the last decade have been classified in this paper under the headings of:

- E-Business oriented systems
- Freight Operation (proprietary systems)
- Intermodal Transport operating systems (spanning over a number of modes and actors)
- Site-specific ICT systems
- Transport and other Public Administrations related systems
- City logistics
- E- Freight.

There is however a lot more work to be done and new and more challenging tasks ahead.

Perhaps the most likely developments in the future will come along the following three lines or directions:

a) More vehicular and infrastructure intelligence.
b) Improved and more integrated electronics for location, tracking, and communication, and the associated information-technology systems.
c) New intelligent models and algorithms to process the data and information gathered (with the systems developed so far), and transform this information into timely and meaningful advice tailored to the needs of the different stakeholders along the different transport chains.

In other words the main challenge will be to drastically increase the **intelligence of freight transport operations** and make it available to all players in the field irrespective of their size**.**

The areas of application of the above are of course many and varied. This paper believes that the following will be the main areas where most of the attention will be directed in the coming years:

- *City Logistics* i.e. the integrated management of freight movements within urban areas.
- *Advanced models and methods* in order to optimize the design and performance of Freight Transport Operations. Practically all decision issues associated with the design and operations of an advanced freight transportation system must be re-addressed within the framework of ITS and their applications.
- Creating a truly *e-business environment* for Freight transport.
- Creating the framework for the full exploitation of capabilities of "intelligent" freight i.e. the *e-freight* environment of the future.

Another area of intense work will be brought about, strangely enough, by the on-going economic crisis situation which started in mid 2008. It will be based on the "recovery" funds that major governments are now making available for new initiatives in the "Research and innovation" field in order to create growth and employment in the long run. The EU's *Green Car initiative* i.e. the development of the next generation "clean" cars of the future (electric cars, and others) is a prime example of such area.

ITS and its related systems and services will be the paramount force for the future development of Freight Transport and Logistics systems. Ultimately, to reap the benefits of such ITS systems and services, freight carriers will also have to adapt with new forms of business and financing practices. They will also have to rely more on the capabilities of integrated, advanced analytic planning and operation decision support systems for their strategic as well as day to day decisions.

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