ATLANTIC

A Thematic Long-term Approach to Networking for the Telematics and ITS Community

A Partnership of ITS Communities in Europe and
North America

DISCUSSION PAPER

Intermodal Freight, Pre-clearance & Logistics

Freight ITS

Prepared by

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In collaboration with Participating Partners and Sponsors

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Preface

ATLANTIC (A Thematic Long-term Approach to Networking for the Telematics and ITS Community) is an international cooperative undertaking that aims to foster information exchange and policy debate related to the application and development of intelligent transport systems (ITS). ATLANTIC originated as a project sponsored by the European Union under the 5th Research Framework with self-sustaining partners in Canada and the United States. ATLANTIC is organized into 8 work groups focused on different topics related to telematics and ITS. This document is the product of one of the Canadian work groups to benchmark and assess the state of ITS practice, research and development in Canada.

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The ATLANTIC Canada network node is sponsored by Transport Canada, the Ministry of Transportation of Ontario and le Ministère des Transports du Québec, and jointly managed by the ITS Center and Testbed of the University of Toronto and the Centre de recherche sur les transports of the Université de Montréal. The core team providing overall leadership for ATLANTIC Canada includes Professor Baher Abdulhai (Toronto), Professor Teodor Gabriel Crainic (Montréal) and Dr. William Johnson (Ottawa).

The Canadian Work Group 2.1 Intermodal Freight, Pre-clearance & Logistics is jointly managed by a leader, Professor Teodor Gabriel Crainic, École des sciences de la gestion, UQÀM and the Centre de recherche sur les transports, Université de Montréal, and a rapporteur, Dr. Lewis Sabounghi, Principal, Sabounghi & Associates. They provided the intellectual leadership and writing skills to assemble and document the synopsis and discussion papers with input and contributions from a network of Work Group members. The names of Work Group 2.1 members and contributors appear in Annex A. Special recognition is extended to Professor Michel Gendreau, Dr. Denis Lebeuf, Mrs Diane Nash, P.Eng., and Dr. Javad Sadr for their extensive contributions.

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ABSTRACT

The topic of Working Group 2.1 was defined originally by the European partners of the ATLANTIC project as *Intermodal Freight, Pre-clearance and Logistics*. The leadership of the Canadian ATLANTIC network interpreted this topic in its broadest sense of ***Freight ITS***. The present Discussion Paper presents the main results of the Working Group 2.1 efforts (electronic data interchange standards are the topic of a companion document). It starts with a brief presentation of freight transportation, followed by a general view of Freight ITS and enabling technologies. The next sections are dedicated to Commercial Vehicle Operation Systems, including border-crossing issues, Advanced Fleet Management Systems, City Logistics, and e-business. The document concludes with perspectives on Freight ITS in Canada and a series of research directions.

RÉSUMÉ

Le domaine d'intérêt du Groupe de travail 2.1 fut défini initialement par les partenaires européens du projet ATLANTIC comme ***Intermodal Freight, Pre-clearance and Logistics***. La direction du réseau canadien ATLANTIC a interprété cette appellation dans son sens le plus large de ***Systèmes de transport intelligents pour le transport de marchandises*** **(*Freight ITS*).** Le rapport présente les principaux résultats du Groupe de travail 2.1 (le sujet des standards pour les échanges électroniques de données est traité dans un autre document). Il débute par la présentation du transport des marchandises, ainsi que des systèmes de transport intelligents et des principales technologies qui lui sont dédiés. Les prochaines sections traitent les systèmes dédiés aux opérations des véhicules commerciaux, les systèmes avancés de gestion de flottes, la logistique urbaine et les affaires électroniques. Les perspectives pour les systèmes de transport de marchandises intelligents au Canada sont discutées dans la conclusion du rapport, ainsi qu'une série de sujets importants de recherche.

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TABLE OF CONTENTS

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Introduction

The initial driving force for the development of *Intelligent Transportation Systems* (*ITS*) has been the realisation that further infrastructure construction could no longer be the only answer to address the increase in transportation demand and the various problems that it inevitably creates. The obvious answer to the need to increase significantly the capacity of transportation systems was to try to make them more efficient through an integrated use of the latest developments in various areas, infrastructure and vehicle technologies, electronics, telecommunications, computing hardware, positioning systems, as well as advanced data processing and sophisticated planning and operation methods. Over the past 15 years or so, one has thus witnessed tremendous efforts aimed at creating and deploying a new generation of transportation systems designed to control congestion, increase safety, increase mobility and enhance the productivity and effectiveness of private and public fleets.

In the beginning, ITS research, development, and investment focused on urban automobile transportation and a public organisational structure and management. It has now evolved to include all types and levels of transportation, persons as well as freight, for which private industries offer a variety of extended, adapted and targeted services. Tremendous challenges and opportunities exist for ITS research, development, and business, particularly in the area of freight transportation which, until recently, appeared relatively less prominently on the agenda of ITS stakeholders. Indeed, the development of Freight ITS and the evolution of the freight transportation industry are closely related, particularly relative to the use of information and decision technologies in response to the tremendous shift in commercial and industrial practices of the last decade. This is in stark contrast to most other ITS areas where the needs of people mobility in congested urban centers constitute the overwhelming driving force.

New challenges for the freight transportation industry result from major changes affecting supply chains and logistical processes in trade and commerce. A first factor is the strong impetus toward inventory reduction that led to the “Just-in-Time” procurement practices and, more recently, to just-in-time replenishments of goods in the retail industry. The powerful trend toward the globalization and liberalization of markets and the creation of free trade zones constitutes a second major changing factor. A restructuring of manufacturing and distribution channels worldwide has accompanied the globalization of the economy. Production units are re-located and the components required for final assembly of complex industrial products are often brought in from many distant locations. All the while, trans-national centralized warehousing facilities and value-added distribution centers are changing the flow of goods almost everywhere.

The development of Internet-based electronic business is also strongly contributing to the transformation of the freight transportation industry. 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 e-commerce activities. These changes have certainly resulted in higher demand for transportation. They have also increased the requirements for freight transportation services in terms of enhanced customer value: reduce transportation and distribution costs, while responding to the customer needs in terms of delivery time and reliability. Moreover, events such as 9/11, the war on terrorism, and the war on drugs have created potential impediments to the flow of goods due to safety and security threats that can only be mitigated through the use of technology and increased efficiency. These factors have put, and continue to put, tremendous pressure on freight carriers and managers of intermodal facilities to reduce and control costs, to plan and operate efficient, timely, and reliable services, and to react rapidly to new customer requests, emerging or shifting business opportunities, and changes in the economic and regulatory environment.

The freight-transportation industry bases a significant part of the answer it offers to these challenges on information and decision technologies: two-way communication, location and tracking devices, electronic data interchange, advanced planning and operation decision support systems, and electronic business. Intelligent Transportation Systems integrate and enhance these technologies within the firm, as well as through the linkages and exchanges between the firm and its environment (customers, partners, regulators, etc.)

This report aims to assess ITS achievements with respect to the transportation of freight and to identify promising research and development directions. While the situation in Canada is our primary concern, we believe that it cannot be isolated from main international developments. We base our presentation on this assumption.

Similar to many other ITS areas, Freight ITS development proceeds along three major, parallel but complementary, directions. The first concerns vehicular and infrastructure developments. While acknowledging the importance of this direction, according to the definitions of the ATLANTIC Working Groups, it was not assigned to Work Group 2.1. Therefore, we address only the second and third directions in this paper. The second direction concerns the electronics, location, tracking, and communication **hardware**, as well as the associated information-technology software. The third targets the **methodologies** – models and algorithms – required to process the data and transform it into timely and meaningful information and intelligent advice for advanced system and fleet planning, management, operations, and control systems. The ultimate performance and long-term success of ITS depends on a balanced and harmonious integration of these two aspects. It appears, however, that governments and industry privileged the second direction to the detriment of the third. While it is true that this phenomenon may be observed elsewhere, it is particularly strong in Canada, though recent initiatives of Transport Canada seem to indicate a change of direction. We hope that these initiatives will continue on a regular basis and that a re-structuring of the financing processes and a strong participation of provincial authorities and industry will accompany them.

We start with a brief presentation of freight transportation. It is followed by a general view of Freight ITS, Electronic Data Interchange and a few other important enabling technologies. The next two sections are dedicated to the two main categories of systems in Freight ITS, *Commercial Vehicle Operations* (*CVO*, including border-crossing issues) and *Advanced Fleet Management Systems* (*AFMS*). The concept and perspectives of City Logistics are introduced next, while the last section is dedicated to the convergence of Freight ITS and e-business. Throughout the presentation we attempt to illustrate how the introduction of better decision-support software may very significantly improve the ultimate performance of Intelligent Freight Transportation Systems. We conclude with a series of research directions and perspectives for Freight ITS in Canda.

A companion document presents the issues and current efforts dedicated to the development of a coherent set of standards for electronic data interchanges in ITS and the logistics chain (Sabounghi 2004).

Freight Transportation

Demand for freight transportation derives from the interplay between producers and consumers, and the significant distances that usually separate them. Producers of goods require transportation services to move raw materials and intermediate products, and to distribute final goods in order to meet demands. Producers of services also require transportation to receive the materials they need and reach their customers. Carriers supply transportation services. Railways, shipping lines, trucking companies, and inter-modal container and postal services are examples of carriers. Considering the type of service they provide, ports, inter-modal platforms, and other such facilities may be described as carriers as well. Shippers are either the producers of goods or some intermediary firm that links demand to supply (e.g., brokers, freight forwarders third-party logistics firms, etc.). Governments contribute the infrastructure: roads and highways, as well as a significant portion of ports, internal navigation, and rail facilities. Most of the ITS infrastructure is provided by governments or under government supervision and encouragement. Governments also regulate (e.g., dangerous and toxic goods transportation and border-crossing procedures), and tax the industry.

When examining freight transportation, one often distinguishes between producers that own or operate their own transportation fleet (who then become carriers for their own freight), and "for hire" carriers that perform transportation services for various shippers. From an ITS point of view, a more interesting and practical classification differentiates between:

(1) The transportation system of a region and the services of a particular carrier; this broadly corresponds to the CVO versus AFMS distinction.

(2) Long haul transportation and distribution (pick up and delivery) problems.

(3) Customized and consolidation transportation.

Pick up, delivery and, more generally, distribution problems are often grouped under the name *Vehicle Routing Problems* (*VRP*) and usually address issues related to "local" movements between terminals and customers. Vehicle routes usually start and end at the same depot and perform several pickup or delivery operations or a combination of both. VRP-type of transportation activities are thus performed over relatively short distances and time periods. A significant part of freight vehicles moving within urban areas is performing VRP-type operations. Vehicle routing operations are essential components of distribution systems and complement long haul transportation activities.

Truckload trucking offers a typical example of door-to-door, *customized* long distance transportation. In this mode, a vehicle is usually dedicated to each customer. When the customer calls, a truck with a driver or driving team is matched to the load and dispatched to move it. At its destination point, the truck is unloaded, and the driver calls the dispatcher to give his position and request a new assignment. The dispatcher may indicate a new load, ask the driver to move empty to a new location where demand should appear in the near future, or have the driver wait and call later. The truckload carrier thus evolves in a highly dynamic environment, where little is known with certainty regarding future demand. Service is tailored for each customer and the timely assignment of vehicles to profitable demands is of the utmost importance. Efficient resource management and assignment methods coupled with information and decision support systems are required to fulfill these goals and maximize the volume of demand satisfied and the associated profits, while making the best use of available resources: drivers, tractor and trailer fleets, etc.

Customized transportation is not always the most appropriate answer to shipper's needs, however. The relations and trade-offs between volume and frequency of shipping on the one hand, and the cost, frequency, and delivery time of transportation on the other hand, often dictate the use of *consolidation* transportation services, where the same vehicle or convoy is used to serve simultaneously various customer demands. Less-Than-Truckload (LTL) motor carriers, railways, shipping lines, regular and express postal services, etc., perform freight consolidation transportation.

Consolidation transportation carriers and fundamentally all intermodal transportation systems operate so-called *hub-and-spoke* networks. In such systems, service is offered between a number of origin-destination points that is significantly larger than the number of direct, point-to-point services operated by the carrier. Then, to take advantage of economies of scale, low demands are moved first to an intermediate point, a hub, such as an airport, port, rail yard, or intermodal platform. At a hub, traffic is consolidated and massive flows are routed to other hubs by high frequency, high capacity services. Lower frequency services, often operating smaller vehicles, are used between hubs and origin/destination terminals. Such an organization allows a much higher frequency and quality of service among hubs, and a more efficient utilization of resources. Its drawback is the increased delays due to longer routes and the time spent in terminals. This explains partly why there are hardly any "pure" hub-and-spoke systems in operation, direct transportation being organized for high demand or high priority origin-destination pairs. An example of this trend is the creation of the intermodal subdivisions of North-American railways to ensure efficient movements of containers among the major ports and industrial centers of the continent.

To mitigate the drawbacks of hub-based operations, consolidation carriers engage in rather sophisticated planning activities. The carrier operates a series of services, each characterized by its own route, stops, frequency, vehicle and convoy type, capacity, speed (travel time), and so on. Internally, services are often collected in an operational plan (also referred to as load or transportation plan), generally accompanied by a schedule that indicates departure and arrival times at the terminals of the route and that is partially or totally available to customers. The aim of the load plan is to ensure that the proposed services are performed as stated (or as closely as possible), while operating in a rational, efficient, and profitable way. It also indicates how demand is moved though the system using its terminals and transportation services. A resource-efficient operating plan and schedule that meet customer expectations, competitive rates, and an on-schedule operation are pre-requisites for a successful carrier.

Many carriers and terminal authorities operate or are part of intermodal transportation.

There is no simple, clear definition for *intermodal transportation*. The term is many things to many people, from dedicated-rail services to move massive quantities of containers and trailers over long distances, to national planning, to door-to-door service for shippers, to a major strategy to define the European Community transportation policy.

In one of its most widely accepted meanings, intermodal transportation corresponds to a multi-modal chain of container-transportation services. This chain usually links the initial shipper to the final consignee of the load and takes place over relatively long distances. Several carriers using different transportation modes ensure transportation. It is interesting to notice that, increasingly, large consolidation carriers offer door-to-door transportation by using other carriers where their services do not reach (e.g., a maritime company that owns or controls land carriers). They become, in fact, freight forwarders and engage in intermodal transportation.

The transfer from mode to mode is performed at intermodal terminals. Actually, all consolidation-type carriers, less-than-truckload motor carriers, railways, express mail services, regular container navigation lines, land container transportation, etc., rely heavily on terminals to perform consolidation operations: of freight into vehicles and of vehicles into convoys (e.g., trains, road or barge trains, ships). Many of these terminals are intermodal terminals, that is, they are designed to accommodate vehicles of at least two different transportation modes and to facilitate the transfer of freight, possibly following classification and consolidation activities, from one transportation mode to another. Ports, airports, rail terminals, motor carrier break-bulk facilities are typical intermodal terminals. Any unexpected delay at a terminal disrupts the flow of goods and vehicles with a strong negative impact on the carrier schedule and reliability as well as on the delivery date of the shipment. In today's economic and production environment, this is something shippers and carriers alike aim to avoid (almost) at all cost.

Border-crossing facilities are also part of intermodal transportation for international commerce. Some of these facilities are located within maritime and air ports while others are standalone facilities. In all cases, the efficiency of transportation, and particularly that of intermodal transportation and logistics chains, is heavily dependent upon the efficiency of terminal and border-crossing facilities.

One must emphasize the importance of containers for international commerce and intermodal transportation. Container-related transportation activities have witnessed a remarkable growth over the last 10 years and the trend does not show any sign of slowing down (Koh and Kim 2001). Containers are used to perform a very significant part of international exchanges. Without container-based efficient intermodal transportation, it would be very difficult to conceive and implement the globalization of the world economy and the current production and distribution industrial paradigms. The efficiency of container-based transportation is vital to a country such as Canada that relies heavily on international commerce and whose transportation system constitutes an important component of international intermodal chains, most of which involve the United States.

A strong initial impulse to container-based transportation came from the increased safety it offered regarding loss and damage. Undeniable advantages in terms of reduced cargo handling and standardization of transportation and transfer equipment translate in cost economies and efficient, worldwide door-to-door intermodal service and fuel the growth of the industry. The heightened attention to security characterizing the beginning of the third millennium contributes to the further increase of the volume of container-based transportation. It also increases the delay that container movements may experience with dire impacts on the economic performance of the corresponding firms and, ultimately, to the competitive advantage of Canadian ports and transportation firms. ITS technology and decision-support systems may significantly help to address the issue.

Intelligent Freight Transportation Systems

The core of ITS consists in obtaining, processing, and distributing information for better use of the transportation system, infrastructure and services.

Prior to examining the components of Freight ITS, however, it is important to remember that the ITS idea is not a brand new concept emerging suddenly, but rather a logical evolution of transportation management drawing on old and new technologies. What is new about ITS is the vision of a *globally integrated framework realising a synergy between* previously isolated *systems*. The rapid and concurrent development of electronic exchanges and partnerships is exacerbating the integration requirements. Integration for ITS and e-business alike is not a simple task, however, as it must engage with a large array of disparate entities covering three broad areas: technical, political, and geographical.

At the technical level, ITS brings together the fields of transportation planning, telecommunications, computing, vehicle and electronics manufacturing, and infrastructure construction. Many political entities are involved in the development, deployment, and operation of ITS: government agencies at the national and local levels, highway operators, carriers, equipment manufacturers, system vendors, and service operators, etc. They must all collaborate to implement and run a system that is composed of a mixture of public and private goods and services. A geographical integration must also be achieved at a regional and, in many cases, international levels. An end user, a container carrier for example, does not like to be forced to buy a different set of equipment for each city or country it intends to travel to. ITS is all about mobility, it is not meant to infringe on it! The efforts aimed at the development of standards and national architectures attempt to address these issues.

It is traditional to examine Freight ITS according to the scope of the systems classified in two broad classes: *Commercial Vehicle Operations* (*CVO*) for system-wide, regional, national, or continental applications and *Advanced Fleet Management Systems* (*AFMS*) dedicated to the operations of a particular (group of) firm(s). Although different in scope, both categories of systems require a number of enabling technologies, some of which are already firmly established, some that are still emerging, many of which are also firmly supporting the e-business activities of the firm.

The continuity in the ITS evolution is illustrated by the strong relations between *Electronic Data Interchange* (*EDI*) and freight transportation. One may argue, in fact, that the common ancestor to CVO and AFMS developments is the adoption by the freight transportation industry of EDI, two-way communication, and vehicle (and cargo) location and tracking technologies (e.g., Allen, Crum, and Brauschweig 1992, Johnson, Allen, and Crum 1992, Crum, Johnson, and Allen 1998, Roy, Bigras, and Crainic 1997, Walton 1994, etc.). This area of development is still going strong.

One can define EDI as the inter-organisation, computer-to-computer exchange of business documentation in a standard, machine processable format (Emmelhainz 1990). Its popularity has grown rapidly due to customer (shipper or large carrier) requirements as well as several benefits associated with its use: minimisation of manual data entry, increased transaction speed and accuracy, lower communication costs, and simplification of procedures. Major shippers (e.g., the auto industry), large carriers (e.g., railways) or infrastructure managers (port authorities) have initially promoted the utilisation of EDI in the transportation industry, and they continue to be among the heaviest users of the technology. Smaller carriers followed, motivated mainly by the need to increase customer service and remain competitive. Pre-clearance activities in CVO-equipped corridors or regions and at maritime and land border crossings require the utilisation of EDI for information transmission among shippers, carriers, and officials. EDI supports advanced fleet management systems not only to enable communications between dispatchers in control centers and vehicle operators in the field, but also to ensure timely and correct data delivery to the planning and monitoring systems of the firm. (Golob and Regan 2000a,b, 2001a,b, 2002a,b, 2003).

The continuous improvement and integration of Global Positioning Systems (GPS) and communication technologies resulted in the improvement in the quality (up) and prices (down) of such systems. This means wider acceptance of these technologies and their utilisation in many modal and inter-modal settings. The current focus of EDI development is on wireless communications, the use of Internet, and the integration of the various technologies and data (Hook, 1998).

EDI, GPS, Automatic Identification Systems and similar technologies are also playing a continuously central role in freight terminals with significant impact on the performance of transportation systems, particularly intermodal transportation, and logistic chains. Significant progress has been accomplished in introducing automation and advanced information and decision technologies to freight terminals, port container terminals in particular (e.g., Arendt and Speidel 1999, Giannopoulos and Shinakis 1999). Considerable efforts are still being undertaken, while many innovative projects are proposed around the world.

It is remarkable, in fact, that EDI was one of the strongest initial enabling factors of partnerships and alliances between large numbers of carriers and shippers, before "electronic commerce" became a household name. This trend is actually leading to the electronic integration of carriers, operators of inter-modal transfer facilities, and shippers with common interests in the movement of certain commodity groups or the utilisation of particular infrastructures (Sunstrum and Howard 1996). Information technologies and appropriate planning and operating management methods and instruments are required to support and enhance such virtual business-to-business communities of interest (e.g., the *European Cooperative Resource Management of Unit Loads* - *COREM* and the *Trident* - *Transport Intermodality Data Sharing and Exchange Network* within ERTICO [WR19]).

Electronic commerce and Internet both accelerate the growth of technologies for satellite positioning, vehicle tracking, EDI, two-way communication, and in-vehicle equipment for communication, computing, and monitoring, and increase the challenges associated to their acceptance and efficient utilization (Golob and Regan 2000ab, 2001a, 2002abc, Grant 2000, Hall 1996, Roy, Bigras, and Crainic 1997). The trend is, however, irreversible.

The contemporary international effort to develop standards for EDI exchanges not only for the transportation industry but for the whole range of logistics and supply chain activities constitutes another major example of this trend.

The procedures related to logistics, particularly those relative to international supply networks (of which the "chains" are the traditional, simple incarnation), and intermodal transport are complex and often cumbersome. At work are numerous interactions between different parties, which are guided by many factors, including type of product, country, terms of business, and the methods of operation of both the buyer and the seller. Given the broad range of activities possible, it is hardly surprising that within the context of actually transporting goods, a single transaction may involve many languages (both electronic and human), standards, and operational practices. If intermodal transportation and supply chains are to operate efficiently and effectively, the relationships, actions, and terms used by the different participants must be understood by all.

Seamless exchange of accurate, complete, and timely data at transportation hand-offs has always been important for efficiency and accountability. In addition, there is now a growing understanding of needs for security of transport information, and for transfer of information related to security against terrorism, illegal immigration, as well as theft and traditional contraband. It is imperative that standards be developed to address and facilitate dealing with these needs. Several international organizations and committees focus on these issues for various types of transportation-related activities. It is imperative, however, that the standards developed for various modes and types of terminals be compatible such that a coherent set of standards developed for Freight ITS and the entire logistics chain. The companion document to this discussion paper details these efforts (Sabounghi 2004).

Commercial Vehicle Operations (CVO)

The Commercial Vehicle Operations (CVO) area of ITS has been defined as "*Advanced systems aimed at simplifying and automating freight and fleet management operations at the institutional level*". National or regional authorities, in collaboration with carriers and firms that propose the required technologies, usually initiate CVO projects. The goal is to increase the performance of the infrastructure (mostly highways) and customs systems, simplify and automate government control-related freight and fleet management operations, and, thus, 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 rely heavily on vehicle or cargo positioning systems (GPS or radio frequency network), bi-directional communications (DSRC, radio, satellite, or wireless phone), and EDI. The importance of CVO applications has been acknowledged quite early on in ITS history, and a significant number of CVO projects have been undertaken or are currently under way.

Initial deployment efforts of CVO technologies have been organised around so-called "corridors". A corridor is typically organised around a major highway, or a system of highways, that cross several regional or national jurisdictions. The goal is to increase the fluidity of truck traffic and to offer seamless interstate or inter-nation border crossings, while ensuring adequate levels of control and reporting relative to regulations on safety, traffic, customs, and so on. 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 are among the main technologies used. Corridor projects usually involve national and local governments and agencies, private technology providers (who, sometimes, also contribute significantly to the financing of the technology deployment), and, obviously, carriers.

Several corridor projects have been undertaken in the second half of the 90's (Crainic, Gendreau, and Lebeuf 2001). In the United States, these efforts have led to the establishment of two major continental systems, the *North American Pre-clearance Automated Safety System* (*NORPASS*) and the *PrePass Program*.

Over 67 000 trucks were registered with NORPASS [WR5] at the time this report was written (March 2004). The system includes several member and partner states in the United States. British Columbia is the only official Canadian member. The PrePass [WR6] network covers a much broader area of the United States. At the beginning of March 2004, 254 495 vehicles were registered with this system. Both systems offer essentially the same services (weight-in-motion and electronic pre-clearance) and are based on transponder technology. The technology now offers transponders that may be used with both systems. A carrier using such transponders and aiming to operate within both systems must register with each system separately, however, and pay the appropriate fees.

The *I-95 Corridor Coalition* brings together state authorities as well as a large gamut of stakeholders in a broad region of the United States, from Main to Florida [WR7]. In Canada, New Brunswick is associated to the coalition. The goal of the coalition is to improve multimodal transportation services in the region through information sharing and coordinated management and operations. The scope encompasses ITS in quite a broad sense to also include CVO.

The *TruckScan system* installed in the state of New South Wales in Australia (Reid and Myers 1996) uses visual recognition systems coupled to electronic databases, in-motion screening testing for weight (per axle and overall), length and height, and vehicle guidance signs and tracking systems. This passive system is designed to automate and improve the roadside checking of vehicles.

In Japan, the emphasis is on the real-time collection of truck operational status and its distribution as basic data to operators. A significant effort is also directed toward the development of integrated and automated terminals, also called “logistic centers”. An automated, platoon-based commercial transportation system is also envisioned. The goal is to enhance the efficiency of commercial and logistics activities [WR22].

In the European Community, the European Commission and the member states have embarked on a comprehensive effort of research, development, and deployment of ITS. It is an exemplary effort in its reach and scope, as well as in the framework it established for collaboration and partnership among all stakeholders – government and public agencies, private firms, consulting bureaux, universities, research centers, and so on. The website of ERTICO [WR19] together with those of its members detail the many projects undertook in Europe. Two main directions are defined for Freight ITS in the policy of the European Commission (the White Paper may be found on the site of Directorate General for Energy and Transport [WR20]). The first concerns the connection of the countries of Central and East Europe to the rest of the continent. ITS is seen as an essential tool to achieve this objective. The second direction concerns the development of intermodal transportation as the main mechanism to influence the current mode choice that is heavily biased toward trucks and highways. The document argues that the improvement of infrastructures, such as posts, and the enhancement of information and decision systems, will result in some of the cargo currently “on the road” to move to less environmentally invasive means of transportation such as rail and coastal and fluvial navigation.

Several CVO projects have been completed in Canada, including (Fu, Henderson, Hellinga 2003)

- Weight-in-motion station with Automatic Vehicle Identification System, to allow compliant vehicles to bypass, in Port Man, Vancouver - Surrey, British Columbia;
- The *CoastView* project in British Columbia to monitor hazardous materials transportation in the coastal waters and ports of the province;
- The virtual station, weight in motion, Saskatoon, Saskatchewan;
- Weight-in-motion and pre-clearance system at Long Creek Station, New Brunswick; The Atlantic Provinces are currently working toward an integrated ITS/CVO development and deployment plan.
- The I.R.I.S. (*Infra Red Inspection System*) in Ontario to screen commercial vehicles while in motion for brake defects.

A major class of CVO projects, particularly widespread in North America, concerns the operations of border crossings. This area has acquired a sense of urgency and high priority following the terrorist attacks on the United States and the continuing terrorist threat. Ports have thus become prime targets for ITS and e-business projects with security issues as the driving objective. While the urgency has been primarily felt in the United States [WR3] (Transportation Research Board 2002), border CVO systems are being developed worldwide. The main goal was and continues to be to clear drivers, vehicles, and cargo in order to speed up the passage of vehicles (trucks, containers, railcars) carrying manufactured and agricultural goods through the border inspection facilities, within the parameters set by the border control requirements in terms of security, immigration, illicit cargo, agricultural controls, etc.

The current state of the world affairs and the U.S. response has elevated these issues at a level of urgency and complexity never felt before. The creation in the United States, Canada, and elsewhere of new government structures dedicated to security issues including customs and border control illustrates this urgency. The U.S. Customs Container Security Initiative [WR3] that requires the inspection and pre-clearance of a certain proportion of containers **before** they leave the port of origin or the last major transhipment port illustrates the increased complexity of ITS/CVO border issues. The requirement by the U.S. Customs and Border Protection agency for advanced transmission of cargo information for shipments destined for the United States [WR3] emphasizes the central role and major challenges for Freight ITS in this context.

The delays at United States ports as well as at borders with Canada and Mexico have increased tremendously and are influencing the efficiency of commerce and supply chains. Projects initiated in the 90's addressed the issue of the harmonization of technologies and procedures at United States borders with Canada and Mexico (e.g., the *North American Trade Automation Prototype – NATAP –* and the *International Border Clearance Program*; Ericson and Johnson 1996, Easley and Flanigan 1997, Bergan and Bushman 1998, Crainic, Gendreau, and Lebeuf 2001). Such projects are no longer sufficient.

In Canada, the border ITS/CVO response comes from both the provincial and federal government levels. Provincial authorities are major players in the installation of Advanced Traveller Information Systems (ATIS) at major border control points. Further illustration of the interest and involvement of provincial governments in ITS as an enabling factor for efficient and secure custom operations is found in the resolution (28-5) adopted by the New England Governors and Eastern Canadian Premiers at their September 2003 conference. This resolution included directives for the Standing Committee on Trade and Globalization to "*continue work toward improvement and increase of cross-border trade by [...] promoting standardized and compatible ITS technologies and the accelerated deployment of customs clearance and pre-clearance initiatives.*"

The Canadian Government created in December 2003 the Canada Border Services Agency for an integrated Canadian response to the needs and challenges of contemporary international travel and trade on the one hand and the corresponding international inter-agency collaboration, on the other hand [WR11]. As of 2002, Canada has participated in the project initiated by the United States to inspect containers before the beginning of the journey. Canadian agents are now in place at a number of U.S. ports (similarly, U.S. agents are stationed at Canadian ports). Canada is also actively participating in the *Free and Secure Trade* (*FAST*) program (from 2003 on) that aims to align the U.S. and Canadian customs commercial programs to support moving pre-approved goods quickly across the border for enhanced supply chain management and operations. The program is based on registering and pre-approving import/export firms (shippers), carriers, and drivers. The project is already in various stages of applications at several border-crossing points. It is planned major commercial border-crossing points will be part of FAST by the end of 2004.

For border ITS/CVO, as for most other ITS areas, the development of the "intelligence" part must accompany that of the hardware and the availability of information. This has led to the creation in 2003 of a first Homeland Security Center for Excellence at the University of Southern California [WR9]. The Homeland Security Center for Risk and Economic Analysis of Terrorism Events is planned as the first of a web of university-based research centers aimed at preventing terrorist threats and minimizing the consequences of an attack. Researchers from several U.S. universities will collaborate in the multidisciplinary activities of the Center. The development of methods and tools for planning responses to threats and actual catastrophic events is a major objective of the new Center. It is noteworthy that the network of centers of excellence of the U.S. Homeland Security Department will complement the network of centers of excellence created in the 90s' at the initiative of the U.S. Department of Transportation.

Many other issues are associated with border Freight ITS and require the development of new methods and software tools. The determination of the optimal number of containers to be inspected to satisfy the security requirements and to limit the delays in ports is an example of such a topic (Lee, Song, and Raguraman 2003, Lewis, Erera, and White 2002, 2003). The Transportation and Logistics Security Group of The Logistics Institute of Georgia Tech [WR8] is pursuing this line of research dedicated to secure and efficient port and maritime transportation.

Advanced Fleet Management Systems (AFMS)

This type of Freight ITS applications corresponds to "*Advanced systems aimed at simplifying and automating freight and fleet management operations at the carrier or business-to-business level*", or AFMS for short.

Once the fleet is equipped and linked to the dispatchers' computers and company's data processing and storage infrastructure a huge quantity of data becomes available for immediate decisions and background analysis and planning activities. Advanced Fleet Planning and Operation Systems aim to process this information and to integrate it to the current transportation plan to achieve a more timely operation, efficient allocation and utilization of the fleet, and satisfaction of customer requests. Differently put, similarly to other ITS areas, there is the need to infuse these systems with **intelligence**. This need is more and more widely acknowledged and it is directly reflected in the national ITS architecture proposals.

Developments, challenges, and opportunities occur at the level of a carrier or of groups of carriers, shippers, and agencies joined through business-to-business networks both in urban centers and over large areas. A number of applications already exist. Some are implemented. Most still appear as proposals and prototypes out of research centers and laboratories. Much more may still be accomplished, however. In the following, we attempt to single out a number of important probable and feasible developments that will use the ITS infrastructure and architecture to do more and perform better.

A multi-disciplinary effort is usually required for successful development and deployment of these systems. Operations research offers the methodologies to represent the problem and to identify solution strategies through various optimization and simulation techniques. Computer science offers the means to address large, realistically sized problem instances in times adequate for the contemplated decision level. Information technologies ensure the adequate flow of data, while operations management build the conditions for the proper undertaking of the plans and strategies. Other management disciplines will address the challenges of introducing advanced technologies in the concerned organizations. In this document, we focus on the issues and the corresponding operations research methodologies that are at the core of the intelligence of ITS. Séguin *et al.* (1997) present a general framework for operations research methodologies in real-time decision-making. Bodin, Maniezzo, and Mingozzi (2003), Crainic (2003), Crainic and Kim (2004), Crainic and Laporte (1997), Powell (2003), Powell, Bouzaïene-Ayari, and Simaõ (2004), Powell, Jaillet, and Odoni, (1995), Christiansen *et al*. (2004), Toth and Vigo (2002), etc. present general survey of operations research methodologies for freight transportation planning and operations. Crainic and Gendreau (2004; see also Crainic, Gendreau, and Lebeuf 2000, 2001) present a more detailed analysis of the links between ITS and operations research.

Most current developments 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 operations in *real-time*.

Indeed, in a typical large or medium-sized city, many private firms and public organizations operate fleets of vehicles of different types to cater to various needs of the population: emergency vehicles (fire trucks, ambulances, etc.), police cars, commercial delivery vehicles, taxis, courier fleets, etc. While some of these fleets have to perform tasks that may be known well in advance or that are sometimes repetitive (e.g., vehicles making regular deliveries to food and detail stores), many of them operate essentially in a demand-responsive mode: the demands for services are not known beforehand and the fleet has to be deployed and managed (re-routed) in real-time to handle them as effectively as possible. The same description applies to “local” pick up and delivery operations performed within a relatively short time period (e.g., a day) in the surrounding area of major intermodal terminals such as ports and major rail yards (Barnhart and Kim 1995).

Carriers that ensure interurban, long haul transportation services also evolve in highly dynamic environments and face similar challenges. Full-load motor-carriers and container transportation companies offer typical examples of such requirements. On the one hand, most demands for empty vehicles arrive dynamically, are very difficult to forecast accurately, and require instantaneous decisions (the customer is on the phone or Internet line) regarding the most appropriate combination of vehicle, tractor, crew, etc., to service the demand. On the other hand, once a vehicle has completed its current task and is empty a decision has to be made concerning its next assignment. Each such “local” decision has a non-negligible impact on the future deployment of the fleet and thus on the long-term efficiency and profitability of operations. The complexity of the impact evaluation is further complicated by the length of the planning horizon, significantly longer in interurban operations than for urban transportation.

The deployment of ITS technologies, in particular accurate positioning devices and in-vehicle computing and communication equipment, opens up the possibility of enhanced customer service and increased productivity by re-routing vehicles in real-time to serve new requests. The information is there. One only needs the appropriate methodology to transform this data into accurate and timely decisions. It is thus normal that a significant line of AFMS research addresses the issues of real-time dispatching, routing, and re-routing of vehicles in response to changes in demand, travel time, congestion, or other conditions of travel conveyed via Advanced Traveller Information Systems, as well as wireless or on-board communication devices.

Traditionally, the organisations facing real-time demand have relied on human dispatchers to manage their fleets. As with any other system relying heavily on human intervention, the performance of these fleets was strongly dependent upon the quality and the experience of their dispatchers. Among other factors, cognitive limitations make it extremely difficult for human dispatchers to effectively monitor and control fleets made up of a large number of vehicles, a situation frequently encountered in many applications. From a modelling standpoint, fleet management problems correspond to combinatorial optimisation problems (e.g., vehicle routing, covering, or design problems) that are notoriously difficult to solve, even in a static context. This, coupled with real-time requirements, explains to a large extent the reliance up to now on human dispatchers. Fortunately, recent developments in the area of algorithmics, in particular the emergence of powerful meta-heuristics, and advances in computing technology, in particular distributed and parallel computing, now make it possible to contemplate tackling in real-time large combinatorial problems in a reasonably effective way. In fact, currently, the main obstacle in most AFMS applications is the need to handle dynamic (stochastic) data.

Interestingly enough, it seems that in some applications simple schemes can be devised to address this issue. The simplest that one can come up with is certainly to base current decisions on current information. Actual experiments with this scheme in the context of courier applications showed that it could be surprisingly effective (Gendreau *et al.* 1998). In most cases, however, such a myopic strategy cannot account for the future consequences of current decisions and policies that incorporate look-ahead capabilities (e.g., Powell 1988, Yang, Jaillet, and Mahmassani 1999, 2004) generally dominate it.

The class of dynamic vehicle routing formulations offers a methodological framework to many real-time routing problems encountered in the Freight ITS domain. As already mentioned, these are difficult problems to solve (Powell, Jaillet, and, Odoni 1995). Yet, metaheuristics, and particularly *tabu search* (Glover and Laguna 1997), have demonstrated their ability to address adequately these challenges (Gendreau and Potvin 1998, Gendreau, Laporte, and Potvin 1997). Most applications address "local"-area problems, which are cases where the geographical region is limited and vehicles (and drivers) return at their home bases at the end of the day. Distribution (pick up and delivery) problems in urban zones belong to this large class of applications, which includes the local operations of inter-urban LTL firms. It is also in this context that most of the studies aimed at real-time dispatching and routing of vehicles have been undertaken. Gendreau *et al*. (1996, 1999) propose an adaptive-memory tabu search method and a parallel implementation that ensures an efficient optimisation of the routes. Experiments performed using a discrete-time simulator showed the superiority of sophisticated optimisation procedures to handle real-time demands as compared to simpler, classical heuristics (Gendreau and Potvin, 1998).

Dynamic traffic simulation offers an alternate approach. Simulation certainly offers the tools to explore and validate operating strategies and appears as part of the core methodology for predicting travel times for Advanced Traffic Management and Traveller Information systems (ATMS). Its precise role in actual real-time dispatching and routing of vehicles has yet to be assessed, however. The challenges here are very similar to those of the ATMS area. The initial exploration of the subject by Taniguchi, Yamada, and Tamagawa (1999) is an encouragement to further pursue research in this direction.

Very few efforts have been dedicated to real-time re-routing of vehicles to satisfy new demands over larger geographical regions and longer periods. Reagan, Mahmassani, and Jaillet (1995, 1996a,b) explore various local rules for the dynamic assignment of loads under real-time information. Simulation experiments tend to indicate that these rules perform relatively well in a stochastic environment (Reagan, Mahmassani, and Jaillet 1998). Additional comparisons to a rolling-horizon, dynamic assignment formulation offer interesting but intriguing results (Yang, Jaillet, and Mahmassani 1999, 2004). Not all strategies are efficient and the information context may influence the impact of stochastic assignment rules. Clearly, much more research is required in this area.

The studies mentioned in the preceding paragraph address issues that belong to the large class of dynamic fleet management problems (Crainic 2003, Crainic and Laporte 1997, Powell, Jaillet, and Odoni 1995). Here, limited resources are dynamically allocated to requests and tasks: empty vehicles, trailers and rail cars are allocated to the appropriate terminals, motive power tractors and locomotives to services, crews to movements or services, customer loads to driver-truck combinations, empty containers from depots to customers and returning containers from customers to depots, and so on. Dynamic and stochastic network formulations have been, and continue to be, extensively studied for these problems. This has resulted in important modelling and algorithmic results, a number of which have been transferred to industry (e.g., Powell *et al.* 1992, Armacost *et al.* 2004). Moreover, recent methodological advances allow to simultaneously manage, in real-time when required, several resources (Powell 2003, Powell, Bouzaïene-Ayari, and Simaõ 2004). This is an extremely rich field for research, development, and application, and it naturally dovetails the Freight ITS and E-logistics areas.

A critical issue in real-time settings is that of response time. In situations such as emergency vehicle management, or when a customer is waiting for a decision, there is no time to compute an "optimal" response when a call is received. This does not preclude, however, the use of deliberate decision-making to optimise the response: one simply has to find ways of anticipating future events in an effective fashion. Thus, for example, one may combine data processing and forecasting methods, optimisation-simulation models, and decision heuristics into comprehensive decision-support systems: The optimisation-simulation models continuously generate and evaluate future conditions and deployment scenarios, while rapid, simpler heuristics respond in real-time to customer requests or changing conditions (congestion, accidents, and so on). Note, however, that this may result in significant computational requirements, since one has to prepare for many potential outcomes. Parallel computing may help address this issue as well as provide more robust solutions.

While custom-service transportation firms, such as truckload, container, and express courier companies, appear as prime beneficiaries of ITS, consolidation-type carriers, railroads, LTL motor carriers, and intermodal facilities, may also attain substantial gains by using advanced information and decision technologies. Of course, the local, pick up and delivery operations of these firms are similar to those described earlier on and would enjoy the same benefits. Similarly, the control in real-time of vehicles during their long-haul journeys (trucks speeding on highways or the pacing of trains) may be significantly improved by the use of ITS technologies.

A very promising research and development avenue consists in a better integration of the information obtained in real-time and the planning and dispatching tools and systems available to consolidation-type carriers. We have already mentioned the possibility to re-route a vehicle already dispatched to serve a new customer or to avoid a congested area (due to an incident, for example). The timely availability of accurate data may enhance the planning of other important activities such as driver and vehicle assignment and empty vehicle management. The connection of port, Customs, and carrier intelligent information and decision systems could enable the scheduling and smooth operation of advanced transportation systems, such as the scheduled-with-booking rail intermodal services currently being developed.

Another area of potential benefits for consolidation carriers resides in a more efficient scheduling of terminal operations and resources. Thus, for example, a terminal working schedule that smoothes out the workload and reduces overtime and terminal congestion could be produced through an analysis of dispatch decisions at the various terminals in the network, combined to real-time data on the location and load of the vehicles and the results of the optimisation-based scenario analysis described above. Similarly, data that is more accurate is available for adjusting the maintenance planning process to real-time events during actual operations. Not many studies have been dedicated to these promising areas yet.

A more challenging area concerns the interactions between the planning of operations, the availability of real-time data, and the actual implementation of transportation plans in an ITS environment. A number of methodologies and decision support systems to assist the planning and operations of freight carriers exist (see Crainic 2003 or Crainic and Kim 2004 for a review). Most are based on static formulations using the carrier's historic data and forecasts. The advent of ITS location and communication technologies offers the possibility to dramatically enhance the quantity and quality of the data available for the forecast and planning processes. This should translate into better plans and operations that are more profitable.

Parallel and distributed computing is an enabling factor for ITS in general and CVO-AFMS in particular. Its challenges are of two different but complementary natures. On the one hand, parallel computing offers the possibility to design data analysis and decision support system architectures to answer efficiently complex requests in real or quasi-real time. Thus, processors may be dedicated to the various tasks of receiving, validating, and formatting data, analysing and aggregating it, forecasting, background simulation-optimisation, real-time selection of the appropriate strategy, etc. On the other hand, parallel computing also offers a challenging perspective with potentially great rewards: to solve realistically formulated and dimensioned problem instances within reasonable times. Each class of problems and algorithms presents its own challenges. It appears clearly, however, that research efforts have to be dedicated both to the decomposition and distribution of tasks corresponding to one particular problem instance and algorithm, and to the development of co-operating search mechanisms that bring to bear on any given problem instance the combined power of several exact methods and meta-heuristics. These ideas that have just begun to be considered (e.g. Séguin *et al*. 1997) have a great potential for the development of intelligent and efficient decision support tools for ITS and other real-time transportation systems.

City Logistics

The transportation of goods constitutes an extremely important activity within urban areas. For people, it directly ensures adequate supplies to stores as well as delivery of goods at home. For firms established within city limits, it forms a vital link with suppliers and customers. There are few activities going on in a city that do not require at least some commodities being moved. Moreover, the urban freight transportation industry is a major source of employment. Yet, freight transportation is also a disturbing activity in urban centres. Vehicles carrying freight move on the same streets and arteries as the private and public vehicles transporting people. These vehicles make a significant contribution to congestion and environmental nuisances, such as emissions, noise, and so on, that impact adversely the quality of life in urban centres. Freight traffic also contributes to the belief that "cities are not safe," which pushes numerous citizens to move out of the city limits. Moreover, the problem is not going to go away any time soon. In fact, the already significant volume of freight vehicles moving within city limits is growing and is expected to continue growing at a fast rate. Major contributing factors to this phenomenon are the current production and distribution practices based on low inventories and timely deliveries (the much talked about "just-in-time" paradigm), as well as the explosive growth of business-to-customer electronic business activities that generates significant volumes of personal deliveries.

One is thus witness to the emergence of an acknowledged need to analyze and eventually control the movements of freight vehicles in cities. The goals are:

- Reduce congestion and increase mobility;
- Reduce pollution and noise; Contribute to reach the Kyoto targets; Improve the life conditions of the city inhabitants;
- Do not penalize the city centre activities such as not to "empty" it.

New organizational models for the management of freight movements within the city limits are called for. The fundamental idea of *City Logistics* is to stop considering each shipment, company, and vehicle in isolation. Rather, one should consider them as components of an integrated logistics system and optimize the entire system accordingly. Coordination and consolidation are at the basis of this 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. City Logistics aims to optimize this system.

Clean city logistics implies the utilization of clean-emission vehicles, at least for part of the operations. Efficient city logistics passes through freight consolidation of various shippers within the same vehicles and an integrated planning of operations and deliveries. These models therefore challenge the city authorities, businesses, carriers, and citizens and require public-private understanding, collaboration, and innovative partnerships. Intelligent Transportation Systems should prove a significant enabling factor towards the conception and deployment of such advanced urban freight management policies and systems.

Historically, one finds a brief period of intense activity at the beginning of the 70's dedicated to urban freight transportation issues. This period yielded traffic regulation to avoid the presence of heavy vehicles in cities to limit the impact of freight transport on automobile movements. Very little activity took place from 1975 to the end of 80's. The increased traffic-related problems and the associated public pressure have revived the interest from 1990 on and have resulted in significant research activities and experimental deployments, some of which continue to operate [WR23, WR24, WR25].

The concept of *City Distribution Center* is 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. Intermodal platforms receive large trucks and smaller vehicles dedicated to local distribution, and offer storage, sorting, and consolidation (de-consolidation) facilities, as well as a number of related services such as accounting, legal counsel, brokerage, and so on. Intermodal platforms may be stand-alone facilities situated close to the access or ring highways, or they may be part of air, rail or navigation terminals. The city distribution center may then be viewed as an intermodal platform with enhanced functionality to ensure coordinated and efficient freight movements within the urban zone. Intermodal platforms are thus an important step towards a better city logistics organization.

Most city-distribution-center projects involve only one such facility and a limited number of shippers and carriers. Different strategies have been tested. Strict licensing practices in use in several Dutch cities impose restrictions on vehicle loads and the total number of trips, and encourage the use of electric vehicles. This has resulted in carriers initiating collaboration activities to consolidate shipments and reduce the number of trips. There is a significant involvement of local and central government and traffic regulations (e.g., delivery hours) were modified to account for the project. The "City Logistik" concept developed in Germany corresponds to "spontaneous" groupings of carriers for coordination and consolidation activities with very light government involvement. Traffic regulation is not modified and the project being a private initiative is supposed to become profitable over a short period. The city logistics system in Monaco is considered a public service. Large trucks are banned from the city. Thus, freight destined to the city is first delivered to the city distribution center, a single carrier taking charge of the final distribution with special vehicles. More details of these ideas and concepts may be found in Duin (1997), Kohler (1997, 2001), Ruske (1994), Taniguchi *et al*. (2001), Taniguchi, Kawakatsu, and Tsuji (2000), Thompson and Taniguchi (2001), etc., as well as on [WR24, WR25].

The licence-based systems have not gained much acceptance outside of Holland. The private city logistic projects have yielded mixed results. It is clear that consolidation in the city distribution center results in extra cots and delays. The hands-off policy of authorities combined with a short-term profitability requirement was not suitable for such innovative projects. Moreover, the use of ITS and advanced fleet management methods was very limited in these initial projects. The system in Monaco performs as planned. Yet, for some time, it was the only one of its kind.

The field is still going strong, however. The new generation of projects integrates ITS technology and advanced fleet management methods. The city distribution center is still at the core of the system, but the private-public partnerships are stronger. Some projects have adopted the Monaco approach. Crainic, Ricciardi, and Storchi (2003, 2004) recently proposed a two-tiered system of distribution centers that aims to cover most (all) carriers and shippers operating over a large urban area by using advanced communication, computing, and decision technologies, as well as environmentally-friendly urban vehicles.

Many research directions must be explored related to the previous 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. Business models are 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 as 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.

Other challenging research directions concern the utilization of existing infrastructures, such as rail or subway tracks, for city logistics activities, and the construction of new infrastructures, such as completely automatic underground systems (Ooishi and Taniguchi 1999, Taniguchi *et al*. 2001).

Methods are also required to evaluate city logistics designs, policies, and impacts. Very few efforts have been dedicated to this issue (Taniguchi and Thompson 2002, Taniguchi and van der Heijden 2000, Taniguchi *et al*. 2001). The same can be said for city logistics and for most ITS components. This makes the issue all the more urgent.

CVO/AFMS and E-business

The current volatility of the stock exchange notwithstanding, the development and utilization trend of e-business is clear and strong. This signals that 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, transportation carriers may take advantage of the convergence between ITS and e-business technologies.

The definition and development of Intelligent Transportation Systems concepts and technologies started well before the business community realized the potential of Internet-based operations, and electronic commerce started to penetrate the business-to-consumer and business-to-business exchange world. The two application domains share several characteristics and enabling technologies, including information and decision technologies, two-way communications, electronic data interchange, computing and data handling technologies, advanced planning and operation decision support systems (Crainic and Gendreau 2003, 2004).

These links appear even more clearly when one observes that the vast majority of business transactions are part of logistics activities. *E-logistics* aim to perform the traditional logistics goals (plan, manage, and control the efficient movement of goods, information, and money) within the "new" environment of partner integration and seamless electronic exchanges. The technologies required to manage the fleets and interact with the external partners (e.g., intermodal terminals and border crossings) are similar to those encountered in Freight ITS.

An interesting development that may directly and significantly affect the operations and performances of freight carriers and their customers is the emergence of Internet-based community 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. By accessing the market, loads could be obtained, thus reducing the need to move empty vehicles to balance the operations. Such markets complement the more traditional auctions of distribution routes of major industrial of retail firms (Ledyard *et al.* 2000).

A number of such markets has started to appear. The market mechanisms do not appear very sophisticated, however. Significant research is required in this area, particularly concerning the possibility to bid on a bundle of loads simultaneously.

In many markets there is the need to negotiate items in *bundles*: allocation of airport take-off and landing time slots (Rassenti, Smith, and Bulfin 1982), wireless communications spectrum licenses (McMillan 1944), distribution routes (Ledyard *et al.* 2000), loads to form closed (i.e., returning at the origin depot) multi-stop routes (Chang, Crainic, and Gendreau 2002a, Figliozzi, Mahmassani, and Jaillet 2002, 2003), supply chain formation and coordination (Walsh, Wellman, and Ygge 2000), and so on. All these cases have one thing in common: they all trade items of a different nature that are interrelated from the perspective of the participants: the value of one item to a participant depends on whether or not the participant managed to obtain (or sell) a number of *other* items. For example, the value of a load to a carrier will depend on whether or not one or several other loads may be secured to ensure a round trip may be constructed such that the vehicle is "always" moving loaded. Items may be *complementary* or *substitutable*. More precisely, if *A* and *B* are two items and $v(\cdot)$ denotes the evaluation function of the participant, *A* and *B* are said to be complementary if $v(A,B) > v(A) + v(B)$, and substitutable if $v(A,B) < v(A) + v(B)$. Loads or containers on freight exchanges are complementary. Several loads that are available at about the same time, between the same pair of cities, are substitutable.

Combinatorial auctions refer to market places in which participants may bid on combinations, or bundles of items. 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 (Abrache, Crainic, and Gendreau 2004, Rothkopf, Pekec, and Harstad 1988, Rothkopf and Park 2001). Significant research is thus 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 to many applications. In the case of freight transportation, combinatorial auctions appear as powerful mechanisms to auction the right to service regular distribution routes and to design freight exchanges where many shippers and carriers meet to determine who will move the loads on the market and at what price.

Participants to combinatorial auctions also face serious challenges. Yet, not much research has been dedicated to these issues up to now. The first and foremost challenge faced by participants in electronic auctions is clearly to identify which items are of interest to them and acceptable price ranges for these items. This is obviously further compounded in the case of combinatorial auctions by the need to build attractive bundles and to price them. A very promising research direction is offered by the development of advisors based on enhanced Advanced Fleet Management Systems to assist carriers when participating to auctions.

Advisors may be defined as specialized decision-support software specifically designed to support participants in the complicated negotiation processes involved in the most sophisticated electronic markets, such as simultaneous auctions for several goods, sequences of sequential auctions or combinatorial auctions. Advisors may have several functions, according to the degree of sophistication of the firm in relation to Internet and the cyberspace: identify promising market places and loads, assess the competition, build and price bids, determine a bidding strategy, conduct the negotiation, close the deal, etc. For most of these functions, the associated models and methods are encapsulated into software agents that help automate the negotiation process. In the following, we focus on one of the critical and most difficult functions: the construction and pricing of bids. Furthermore, we restrict our discussion to freight exchanges, which offer the greatest challenges to participants.

The problem appears simple to state. A number of loads are available on one or several markets. Each load has a number of characteristics, including: time of appearance and duration on the market, time window for pick up and delivery, technical requirements (e.g., refrigerated), service quality requirements, etc, as well as a maximum price the shipper is ready to pay (this information may be explicitly displayed or not). The carrier has one or several vehicles that could be used to serve one or more of these loads. Each vehicle is (or will be) available at a certain moment and location and is requested to be at a given location at some specified time (for a confirmed order, maintenance, crew change or rest period, etc.). The carrier aims to determine sets of loads, one for each vehicle, eventually, that would maximize its profit. The difficulty comes from several sources, in particular, how to estimate the possible revenue for any given load and how to determine the best set of loads to maximize overall profit.

Revenue estimation for specific loads is difficult because when a carrier starts bidding on a load, it may have no idea of the price at which it will finally be adjudicated. This would be of rather little importance if the carrier were interested only in this load, since in that case, all it would need to do is to bid on the load as long as it is profitable. In reality, the carrier is also faced with several other loads, complimentary or substitutable, and needs to derive an estimate of the going price of each load ***before it is auctioned***. Analysis of bidding strategies and knowledge of other carriers' behavior in similar past auctions can be extremely useful in that context (Chang, Crainic, and Gendreau 2002b, Figliozzi, Mahmassani, and Jaillet 2002, 2003). It is also important to note that the advisor component that is responsible for addressing these questions is truly unique and has little to do with the operations management software that may be used by a carrier for its fleet.

The choice of the best bundles of loads in a given setting brings us back to traditional carrier interrogations: what are the attractive loads? Which one to assign to a given vehicle? How much to charge the shipper? This realization clearly highlights the fact that advisors or advisor components handling these functions should be extensions of software for fleet management. We distinguish between two broad classes of advisors: ***independent advisors***, in which the evaluation-selection function is performed independently from the planning process of the carrier, and ***tightly coupled advisors***, in which this function is integrated into the planning process. The main reason for introducing this distinction stems from the desired *modus operandi* of a specific carrier: the firm may not find desirable, or even feasible, to operate its planning process too close to external networks, such as freight exchanges (this would also be the case if one were to use an advisor for finding full loads for fleet repositioning in an LTL context). In such a case, one would like to first extract from the planning software various cost, time and location information regarding the vehicles to feed to the advisor that would then act in an autonomous fashion. Finding good bundles of loads for the vehicles can then be formulated as a network flow optimization problem. In tightly coupled advisors, the information from the freight exchanges is treated similarly to that from other sources (e.g., calls from shippers asking for quotes) and the loads that are auctioned on these exchanges need to be integrated (*mutatis mutandis*) in the planning software. In state-of-the-art fleet management software, this leads to versions of the dynamic, stochastic network simulation/optimization models that have been proposed in recent years.

A critical issue with advisors is the need to develop proper contingency plans in case one ends up losing on loads that had been identified as attractive. Losing a single load in a chain of several ones may turn a profitable bundle into a costly blunder. Thus, one needs to define sophisticated *recourse strategies* capable of addressing the various possible outcomes of a series of related simultaneous or sequential auctions. The only way to fully address this issue is by moving to fairly complex stochastic optimization models, which is probably more easily done in the context of tightly coupled advisors than of independent ones (because in the first case, one would already be working in a stochastic environment). At this time, it is certainly an open challenge to be able to come up with advisors capable of addressing this contingency issue in a simple, yet effective fashion. It is important to point out that this difficulty is compounded by the setting of continuous markets (a situation that is quite likely to be encountered in many real-life freight exchanges) that make any type of combinatorial bidding impossible and thus maximize the exposure risk. The development of advisors specifically aimed at such markets is probably one of major priorities in this whole field.

Significant research efforts are required in all these areas. The development of model and strategy evaluation tools is also a priority. Simulation appears as the methodology of choice. A fascinating question that will also have to be addressed is whether the access to such electronic market places will reduce the stochasticity of operations and reduce the need for sophisticated look-ahead capabilities. The contemplated simulators would help address this issue as well.

Conclusions: Perspectives, Challenges, Opportunities

This discussion paper aims to assess ITS achievements with respect to the transportation of freight and to identify challenges, opportunities, and promising research and development directions. The situation in Canada is our primary concern. We strongly believe, however, that it cannot be isolated from the main international developments. The presentation reflected this assumption.

We examined the Freight ITS field from several complementary points of view: enabling technologies including Electronic Data Interchange, Commercial Vehicle Operations including border-crossing issues, Advanced Fleet Management Systems, the City Logistics concept for integrated urban freight management, and the links and convergence of Freight ITS and e-business. Throughout the presentation, we attempted to illustrate how the introduction of better decision-support software may very significantly improve the ultimate performance of Intelligent Freight Transportation Systems. We conclude with a series of research directions for Freight ITS in Canada.

Similar to many other ITS areas, Freight ITS development proceeds along three major, parallel but complementary, directions. The first concerns vehicular and infrastructure developments. This topic is addressed by the ATLANTIC Work Group 2.2 *Intelligent Vehicles and Vehicle-Highway Systems*. Therefore, this discussion paper addresses the second and third directions only.

The second direction concerns the electronics, location, tracking, and communication **hardware**, as well as the associated information-technology software. The third targets the **methodologies** – models and algorithms – required to process the data and transform it into timely and meaningful information and intelligent advice for advanced system and fleet planning, management, operations, and control systems. The ultimate performance and long-term success of ITS depends on a balanced and harmonious integration of these two aspects.

Canada enjoys a world-class presence in Freight ITS regarding both directions. Canadian firms are present all over the globe performing studies, selling technology, and deploying systems. Canadian university research is cutting edge, in Freight ITS as in several other ITS domains. It is troubling, however, to notice that the quality of Canadian ITS university research is often better known and appreciated outside the country than within. Particularly as far as the methodological – the **intelligence** – aspects of ITS are considered. It appears that governments and industry privileged up to now the hardware aspect to the detriment of the methodological one. In many cases, data provided by very sophisticated devices and relayed through advanced communication technologies is still being processed and acted upon by human operators with little, if any, decision-support tools. There is thus a challenge to drastically increase the intelligence of ITS. While it is true that this phenomenon may be observed elsewhere, it is particularly strong in Canada. Recent initiatives by Transport Canada seem to indicate a change of direction. We hope that these initiatives will continue on a regular basis and that a re-structuring of the financing processes and a strong participation by provincial authorities and industry will accompany them.

Freight ITS deployments in Canada are not numerous yet. One may conclude that the current level of freight-related ITS deployment is significantly more modest than what the activity level of Canadian ITS industry and university sectors might indicate. The situation is evolving, however. The current security concerns and the significant impact border controls have on freight and logistics activities and performance seem to have broadened the awareness of the need for ITS at the federal, provincial, and industry levels. A certain acceleration of the pace of system study and deployment at the Canada-U.S. border illustrates this trend.

Many challenges and opportunities for ITS research and development may be identified. Thus, while many technologies are now accepted and deployed on a regular basis, several issues must still be addressed:

- Standardisation and inter-operability are still a challenging issue, particularly when examined at the continental and world-wide level. The Canadian highway network is not yet completely integrated into the North-American network. Moreover, the level of integration varies widely from province to province. Technological choices should be made carefully to avoid imposing excessive costs to carriers and facilitate not only the North-South integration but also the inter-provincial, East-West, trade. A similar argument may be made with respect to port and container technology. Canada and the provinces should enforce their collaboration as well as their presence to international ITS, transport, and standards organizations.
- Particular attention should be paid to the long-term maintenance of deployed ITS infrastructure and data processing systems at all levels. Unfortunately, recent history seems to indicate that we tend to neglect the maintenance of our public transportation infrastructure. Such an approach would spell disaster when applied to ITS.
- An important research field that should be explored addresses the exchanges and integration of Freight ITS deployed at border crossings and ports, the Advanced Traffic Management and Advanced Traveller Information Systems of the corresponding cities and regions, and the AFMS of the shippers and carriers that use the systems. This involves not only the integration of electronics and communication systems, but also those of the planning and scheduling activities. Being pre-approved means nothing if one must still wait for hours together with other pre-approved vehicles because everybody desires to cross simultaneously!
- An important related research field is that of the management of ITS and security-equipped borders and ports. The efficiency of these facilities is tributary of their design and management methods and processes. The whole field, including the previous topic, is not yet sufficiently addressed and the Canadian research community may make a significant contribution.
- Freight ITS change the way transportation activities are performed. This is exactly what is expected. On the other hand, however, freight vehicles interact with private and public vehicles carrying passengers. Moreover, Freight ITS, CVO systems for example, also interact strongly with logistics activities and industrial value chains. These impacts are not well understood. One lacks the knowledge and tools to evaluate and compare alternate systems, policies, and investments One should be able to evaluate these interactions and the impact of Freight ITS on the general mobility within a given zone or on the logistic activities of particular industrial sectors. Such developments require a multi-disciplinary effort: a thorough representation of the economic, operations, and information and decision technologies used by the various actors, sophisticated optimization and simulation methodologies, parallel or distributed computing environments. The resulting systems would be used not only for policy assessment but also for experimentation and training at the university and industry levels.
- The success of Freight ITS (similarly to most ITS components) is also strongly dependent on the awareness and willingness of its users, producers, shippers, and carriers in particular. How well CVO/AFMS concepts, technologies, and practices are understood and accepted by the various actors constitutes a worthy research area.

City Logistics – the integrated management of freight movements within urban area – constitutes a fascinating research domain, still largely unexplored in North America. Compared to most cities in Europe and Asia, in Canada, we still enjoy the benefits of relatively high capacity street networks and "low" levels of urban congestion. This is rapidly changing. Moreover, the Canadian population is becoming increasingly environment-conscious and demanding regarding the impact of transportation on the environment and the quality of life. City Logistics is still a very young research domain. Even less is known about the applicability of such concepts in North American cities. An intensive research program is required on the technical, design, operational, management, policy, etc., aspects of City Logistics in Canada and North America in general.

The emergence and rapid growth of electronic business both challenges and offers freight carriers great opportunities for improved operations and profits. The convergence of information, communication, and decision technologies used in CVO and AFMS and in advisors for e-markets constitutes a significant advantage in this context.

Significant research is still required in this area, however. We identify several avenues of particular interest. On the market side, one should study the advantages, the development and implementation barriers, and the possible business models for freight electronic markets in Canada and their interaction with the North-American and international markets. On the carrier side, research is required to develop efficient and comprehensive advisors. Three particularly challenging aspects of this issue are the (1) Enhancement of the modeling capabilities and the efficiency of solution methods for the complex, stochastic and dynamic formulations related to identifying profitable bundles; (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. Strongly related to this is the area of coordination of various information sources, agents, and negotiations.

The various applications described in the Discussion Paper illustrate the key role *operations research* models and methods play in the analysis of ITS needs and projects, as well as in the development of the software component of ITS. Such methodologies transform the huge amount of data provided by ITS technologies into useful information that may be either distributed to the various ITS users or transformed into operating policies and instructions. Operations research-based data processing and decision support systems may explore and evaluate the behaviour of the transportation system under various conditions and develop contingency plans, predict the state of the system over the next time periods, generate general or user-tailored itineraries or guidance instructions, plan operations and assist the real-time management of fleets.

Research and development efforts are currently under way in several of these areas, as illustrated in the AFMS section. The methodological developments of recent years in the various fields of operations research, combined to recent advances in computer science, in particular in parallel and distributed computing, put the required models and methods within our reach. More efforts are still needed, however, in particular relative to:

- Real-time allocation of resources and management of operations, including real-time fleet management and vehicle re-routing. The issues are different but equally challenging whether urban or interurban transportation is considered, or whether the real-time decisions depend on the congestion and demand conditions only, or must account for and 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, AFMS (and 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.
- Development of the next generation of urban/regional planning systems that reflect the utilization of CVO and AFMS technologies.
- Arbitration between central processing and the utilisation of the computing power of on-board computers and the next generation of transponder devices.

The Canadian ITS R&D community is ready to take on these challenges and opportunities. **The financing of research, particularly university research is probably the most important hindering factor**. There is almost no funding specifically targeted at transportation research and even less for university-based research.

It is true that Transport Canada has announced recently a number of initiatives for ITS research. A major issue is that this funding is largely considered as contracts. This implies that 1) Only half the funding is offered (this excludes fundamental research); 2) Delays for realization are extremely short, not compatible with a long-term vision of sustained research and development; 3) The evaluation and announcement processes are not transparent and seem to obey political considerations. Moreover, this financing seems limited in time. There is no long-term commitment. The situation appears similar at the provincial level.

A coordinated effort and leadership of federal and provincial ministries, bringing together the industrial and university communities in required. A program of research funding with precise and transparent rules and schedules should be created. Funding should be made available both for large scale cooperative projects and for focussed developments. The ITS network of centers of excellence initiative should be pursued in a more proactive mode. The program should be defined, and funding should be secured, over a period of time compatible with the requirements of innovative, value-creating research. Research projects should be defined for 3-year periods, while Centers of excellence should be supported for 5-year periods (renewal rules should be specified).

Canada has the people and institutions to address the Freight ITS challenges and issues. We need the support and financing to undertake this effort.

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