FOREWORD

Freight transportation is one of Canada’s largest industry sectors, accounting for $40 billion worth of annual revenues each year. Nearly half a million people are employed by approximately 8,000 companies belonging to this industry. Furthermore, the competitiveness of the entire manufacturing sector depends to a great extent on the competitiveness of the transportation system.

Industry Canada is focused on improving the competitiveness of Canadian industry through trade, investment and technology initiatives. Technology roadmaps are our business plans for the latter, identifying the enabling technologies critical to future success. Therefore, we were very pleased when the Transport Institute of the University of Manitoba agreed to champion this project.

The Freight Transportation Technology Roadmap is a tool that will aid the industry, its stakeholders, governments, as well as academic and research groups in identifying technologies that will be essential for the industry to remain competitive in the future. The Technology Roadmap will therefore influence the necessary research and development process and capital investment decisions. This will result in a more profitable and competitive sector.

One of the significant advantages in developing a Technology Roadmap for the Freight Transportation industry include encouraging innovative technological applications in the industry. Another will be the establishment of new technological networks among companies, government agencies, stakeholders and academic institutions.

This report will assist all Canadian Freight Transportation companies, as well as their stakeholders, in strategic technology planning. The roadmap initiative will contribute to building a more competitive and innovative economy. On behalf of Industry Canada, I thank all participants for their indispensable contribution to this important initiative.

John M. Banigan
Assistant Deputy Minister, Industry Sector
Industry Canada

Technology Road Map for Freight Transportation Services
FOREWORD

Freight transportation plays a vital role in the Canadian economy and society, arguably more so than in almost any other country in the world. The reasons are geographical and historical: freight transportation in Canada has played a critical role in moving unprocessed resources from remote hinterlands to international markets. More recently in this process, the challenge has been to add value to goods en route to their final destination point.

The freight transportation industry faces new challenges in a highly competitive and globalizing economy. In particular, changing trade patterns have a direct impact upon the nature and extent of the Canadian transportation system. For example, according to Statistics Canada, one of the most visible trends of the last decade is the shift from traditional East-West traffic flow toward more North-South movements, a clear effect of NAFTA. Changing markets also generate customers with needs that are difficult to predict and respond to. Finally, the ability to source commodities and finished goods from anywhere in the world has broadened the role of transportation to include international supply chain structures. These trends drive new customer demands in which the keywords are: flexibility and mobility, and coordination and integration.

The freight transportation industry is also confronted with the challenges of rapid technological change. These technologies are having widespread impact; they also present opportunities. New technologies may lower costs, increase efficiency, and create competitive advantages for firms, while simultaneously providing solutions to societal concerns over safety and the environment. Alternatively, delays in adapting to rapid technological change may create problems that threaten to put Canadian companies at a competitive disadvantage.

To sustain competitiveness, industry, government and other stakeholders (including researchers) must respond to these challenges in a coordinated fashion. I believe that the Freight Transportation Technology Roadmap can be the beginning of this coordinated response.

Dr. Barry Prentice
Director, Transport Institute
University of Manitoba
PREFACE

This Technology Road Map is the culmination of many months of work, involving several meetings of the Steering Group, two focus group sessions with industry representatives, and a Technology Workshop organized by the Transport Institute of the University of Manitoba. The report that follows is a summary of the background papers that were prepared for this Technology Road Map project.
EXECUTIVE SUMMARY

Freight transportation plays a vital role in the Canadian economy and society, arguably more so than in almost any other country in the world. Historically, freight transportation services in Canada have played a crucial role in moving unprocessed resources from remote hinterlands to international markets. More recently, the goal has been to add value to goods en route to their final destination point. In the future, the freight transportation system will be required to provide low cost, efficient and high quality service to Canadian industry all along the supply chain.

Challenges

The freight transportation industry faces new challenges in a highly competitive and globalizing economy. First, the ability to source commodities and finished goods from anywhere in the world has highlighted the important role played by domestic transportation systems in international supply chain structures. Second, changing trade patterns impact directly upon the nature and extent of the Canadian transportation system. For example, one of most visible trends of the last decade is the shift from traditional East-West traffic flow toward more North-South movements. Finally, changing markets generate customers with needs that are difficult to predict and respond to. These and other trends lie behind new customer demands for flexibility and mobility, coordination and integration.

Industry is also confronted with rapid technological change and associated risks. Delays in adapting to rapid technological change may create problems that threaten to put Canadian companies at a competitive disadvantage.

In transportation, the dilemma of risk management is pronounced because of long innovation cycles and infrequent breakthroughs. In Canada, these “natural” barriers to innovation have been exacerbated by a regulatory environment that offered few incentives to innovate producing a culture of resistance to innovation in the freight transportation services industry.

Opportunities

Economic and technological change also presents opportunities. New technologies may lower costs, increase efficiency, and create competitive advantages for firms, while simultaneously providing solutions to societal concerns over safety and the environment.

The goals of this report are:

- to define the driving forces driving in the freight transportation services industry;
- to identify technologies which meet future market requirements and;
- to address implementation issues relevant to transportation technology development in Canada, in particular those related to R&D policy and funding.

Technology Road Map for Freight Transportation Services
INTRODUCTION

This report presents a Road Map for technological innovation; R&D and technology transfer for freight transportation services (FTS) in Canada.

The FTS industry includes the activity of railways, motor carriers (for-hire) and domestic marine shipping (i.e. Great Lakes and Seaway activity). Together they constitute one of Canada’s largest, most important, industry sectors.

Excluded from the Road Map are international marine shipping, passenger transportation and air freight transport. It should be noted, however, that all these activities are significant to the overall story of transportation innovation. Developments in passenger transport, for instance, spill-over into the freight world, notably in Intelligent Transportation Systems (ITS) applications, and elsewhere where the objective has been to “put more intelligence” into the package, road, or vehicle. In air cargo transport, we note the example of air-road intermodal freight, especially the role of the large integrated cargo carriers (e.g., FedEx, UPS, DHL), as a sector of exceptional innovation and economic significance.

In recent years, the FTS industry has seen the benefits technological innovation can offer. Canada’s railways, for example, have begun implementing new technologies (e.g., new high-powered locomotives), after many years of little innovative activity. Indeed, new technology acquisitions are one of the chief sources of productivity gains in the railway industry in Canada during the last decade.

The trucking industry is using advanced engine and vehicle technologies to reduce fuel consumption and satellite communications technologies to track shipments and improve service to customers.

On the whole, however, the Canadian freight transportation services industry is playing catch up to our competitors when it comes to technological innovation. The reasons are varied, but many relate to the absence of strong market incentives to be innovation leaders.

In an open competitive industry one does not normally expect a noticeable lag between the availability of a cost effective technological advance and its implementation. In Canadian freight transportation, however, lack of competition, as well as high entry costs and high levels of operating complexity, has lead to resistance to innovation and delays in adopting new technologies. In other words, transportation innovation involves a high degree of risk at each stage of the innovative process, including:

- the design and construction process (development risk);
- user acceptance of new technology (acceptance risk).

Regulatory restriction or government market presence is a critical factor. For example, carriers
often must await government approval processes before implementing new methods or products (e.g. truck weights and dimensions). In some commodity sectors (i.e. grain), regulation affects industry competitiveness and therefore innovative activity. Removal of restrictions can have a stimulating effect. For example, the National Transportation Act (1987) and the Canada Transportation Act (1996) have helped reduce existing restrictions, particularly in Canada’s rail sector.

The Road Map is organized into three sections. The next section looks at the current and future forces, be they technological, economic or political in nature, driving the transportation system toward the year 2000 and beyond. These are forces, like changes in trade patterns, that are sure to have continued impact over the medium-term. Many of them are dynamically interrelated and rapidly changing. The Road Map will therefore need updating as conditions change.

The following section describes technological innovation in freight transportation. It identifies technology options and priorities in response to driving forces over the short, medium and long term. It begins with existing and emerging technologies in each of the three modes (and intermodal). The second part of the section identifies enabling technologies that offer opportunities to respond to market forces over the medium term, in particular customer demands for better service. The section concludes with technologies that will be required over the longer term to meet growing societal concerns over the environment.

The final section of the report addresses implementation issues and concludes with options that should be considered for pursuing opportunities presented by the current driving forces, and overcoming existing and continuing constraints in the innovative process.

DRIVING FORCES

The Road Map emphasizes the market basis for understanding technological innovation. As a market-pull initiative, the Road Map highlights both upstream and downstream linkages in a market segment (i.e., the supply chain). As customer needs pull the demand for ever-better transportation services, firms will need to respond with technological improvements that enable the improved “supply” of services (i.e., lower cost, better quality). These technology requirements, or “drivers,” move down the supply chain from carriers to equipment manufacturers and component suppliers.

Market and Service Drivers

The demand for freight transportation services, in terms of bulk, break-bulk and containerized traffic, is derived from Canada’s trade in international and domestic markets. Trade between two countries in turn is determined by a host of general economic factors, many of which are complexly interrelated. It is common, therefore, to emphasize that transport demand is a derived demand.

Technology Road Map for Freight Transportation Services
International Trade and Freight Transport Demand

There are two main markets to be satisfied, an overseas market and a domestic (North America) market.

Overseas Demand
Exports of raw material primarily reflect overseas demand (e.g., for coal in Asia) and are price sensitive because of global supply competitiveness. The fate of Canadian suppliers is directly related to the availability of cost-efficient transport of bulk commodities, as they have high transportation costs. Marine and rail carriers handle the majority of bulk commodity traffic, although trucks often transport them short distances.

Transborder Trade

The North American trade in commodities (exports and imports) reflects the effects of free trade (NAFTA) and the closer integration of the Canadian economy with that of the United States. Some 70% of Canadian trade (by value) is with the USA. Trade in more highly valued goods reflects consumer demand, especially in US markets (e.g., automobiles and automobile parts). These commodities, where transportation is a much smaller part of the delivered price, generally have several transport alternatives to choose from. While low cost transport is important for these commodities, their principle “driver” is competitive service quality. Over two-thirds of Canada-US trade, in terms of value of exports, moves by truck. Very highly valued goods almost always move by truck, often using JIT (“just-in-time”).

Impact of Changing Trade Patterns

Transport demand is affected by changing trade patterns and agreements to liberalize trade. Falling trade barriers create new market opportunities, the effects of which reverberate throughout the supply chain:

- New customers emerge; they have new needs, which are often difficult to predict;
- In response, manufacturers, retailers and shippers are forced to re-engineer their supply chains;
- Carriers in turn are forced to implement changes, including implementation of new technologies, to remain competitive.
- Finally, new services create opportunity for entrepreneurs to take advantage of markets that were previously unavailable.

The supply chain structure itself both defines and drives seven key transportation capabilities:

- Time Compression
- Reliability
- Standardization of Transportation and Logistics Processes

Technology Road Map for Freight Transportation Services
• JIT
• Information Systems Support
• Flexibility
• Customization

Technology Synergies

There have always been synergies between transportation and communications as they have similar “connecting” functions. Synergies between the two can create the critical mass necessary for revolutionizing large complex systems. In the past, innovations in transportation (i.e. railways) triggered “companion” innovations in communications (i.e. the telegraph).

In the twentieth century, however, innovations in information and communications technology have rapidly outpaced developments in transportation, freeing communications from its dependency on transportation.1 This has had important implications for transportation. For instance, information once “glued” to the cargo now precedes it, allowing improved efficiencies throughout the logistical chain. Information flow is now an integrated part of the transportation market (see Appendix A)

IT Drives the Chain

Information technology is finding rapid diffusion in the transportation sector. Indeed, it would be difficult to overestimate its importance. The economics of this process are:

• Supply side. IT’s enabling role facilitates its application and acceptance in transport; most significant is IT’s potential to add value.

• Demand side. Market driven opportunities for IT investment are being created as a result of rapid expansion of the global Information economy.

Unlike some vehicle, propulsion and infrastructure technologies that supplanted prior generations of technology, IT can be incorporated into transportation operations in an evolutionary fashion. There are four characteristics of this process:

1. Rapid technical progress. IT is driven by markets spanning all economic sectors. As a result, IT developments are characterized by rapidly falling costs, while simultaneously increasing performance.

2. Continuous evolution. IT has the capability to continuously improve the performance of existing equipment and infrastructure. Moreover, as an evolving technology it faces less barriers to implementation than new transportation technology which must replace older but still functional equipment. Similarly, IT can be implemented gradually as minor tools that
grow into critical business enablers.

3. **Process re-engineering.** Full realization of IT often necessitates redesign of operational processes.

4. **Widespread application.** The forms of IT finding application in transportation are generally the same ones increasingly used in all economic and social sectors. For this reason IT uniquely facilitates large-scale integration of supply chains and fosters linkages between business processes.

In sum, the emerging scenario of global logistics and rapidly advancing information and communication technologies constitutes an opportunity for transportation to leverage capacity out of existing transportation infrastructure.

**Summary of Industry Trends and Issues**

At present, the freight transportation industry in Canada is dominated by issues that relate primarily to competitiveness in the global environment. These competitiveness issues span a wide range of topics: economic (e.g. costs and risks), political (e.g. legislation and regulation), and social (e.g. safety, labour and environmental.) All of them, together or individually, can have a bearing on whether technological innovation in the industry is successfully implemented.

- **Restructuring.** Many carriers, logistics providers and government transport departments have recently restructured or are in the process of downsizing, focusing on core competencies and reducing costs.

- **Globalization.** All modes of transport are now realizing that they are in a global marketplace. Marine carriers are under more global competition. Truck and rail carriers now must reach across national boundaries to successfully serve their customers.

- **Network Consolidation.** Many transportation companies have set up hub and spoke operations and eliminated some regional facilities.

- **Intermodalism.** Communities who need transport do not think in terms of modality; they think of the objective of transport, which is to move goods and people from origin to destination. From a shipper’s perspective the mode of transport used is less relevant than issues of cost, reliability, timeliness and convenience. In particular, shippers are asking carriers to provide door-to-door service; thus, they will have to offer intermodal service through strategic partnerships or integrated operations.

- **Shrinking Lead Times.** Shippers want to reduce “time” in the system; thus, transportation companies will have be more time conscious and able to trace and track shipments.
• **Focused Production.** Some industries have gone to the “focused factory” concept (i.e. one factory producing one product and supplying all others). The freight transportation industry will have to respond to the time and service demands of this concept.

• **Integrated Logistics.** Some shippers are asking carriers to offer full service logistics services.

• **Quality Management.** Concepts like ISO 9000 are now common in the manufacturing industry. As suppliers to this industry, carriers will have to be quality certified as well.

• **User Pay Systems.** Many governments are moving toward user fees to finance the transportation system rather than using general tax revenues. User pay systems could include, for example, highway tolls and port user fees.

• **Ownership and Operation of Transportation Infrastructure.** Traditionally, governments have been the owners and operators of much of the transportation infrastructure. This is changing in many jurisdictions as highways, ports, navigation systems, and railways are privatized or commercialized.

• **EDI Standards.** Users of information and telecommunications technologies must conform to EDI (electronic data interchange) standards in order for integrated transportation systems to be effective. In the future, a common standard will have to be developed and recognized by all users in order to maximize the effectiveness of EDI.

• **Compatibility.** New and faster computer hardware combined with increasingly sophisticated software has greatly enhanced the use of information and telecommunications technologies in transportation. Overall, costs are decreasing as new systems become more powerful and adaptable. But hardware and software systems must be compatible in order for electronic commerce and integrated information technologies to be effective.

• **Partnerships.** Partnerships are being implemented more and more between shippers, receivers and transportation companies to enable the establishment of better communications systems.

**TECHNOLOGY**

Transport services have been changing as improved technology becomes available or is implemented. Consequently, a technological improvement in transportation may stimulate the demand for transportation services. In general, major transportation innovations have come in bursts, or waves, since the early 19th century. Examples of successive innovations occurred
mainly in the areas of vehicle design and manufacture and new propulsion systems (steamship and locomotive, internal combustion engine, the jet engine, containers and the “mega-ship”), and physical infrastructure (tunnels, suspension bridges, modern marine terminals).

**Technological Change in Transportation**

In its modal character, the modern freight transportation system has focused on achieving engineering advances which provided higher performance vehicles (improvements in speed, size, range and payload), on portions of the total movement of goods, whether it be from origin to terminal, terminal to line-haul, or terminal to destination.

Vehicle evolution has in turn necessitated improvements to physical infrastructure but they have large relative costs and take substantially longer to plan and acquire. In general, vehicle improvements have continued to outpace improvements to infrastructure creating congestion effects and capacity constraints in the system. In economic terms, growth in demand for infrastructure capacity outstrips investment in new capacity. Congestion exerts pressures in all modes to continue to increase vehicle size and range. As this occurs emphasis on control of the traffic on the system ascends to primary importance.

**Existing and Emerging Technologies**

The cost and service characteristics of a transportation mode depend on the technology employed. A cost-reducing technological change can make a given mode more competitive. Similarly, lower product/service prices encourage greater competition. Existing and emerging technologies that achieve cost and performance benefits are listed by mode in Table 1.

*Marine*

Marine technological change in Canada is focused primarily on fuel consumption. Other concerns are improved safety and reducing labour costs. Computer advances allow the integration of the two areas. Electronic engine control, working in conjunction with automatic navigation systems, can automatically adjust engine speed to match traffic flow. The resulting efficiencies decrease costs and increases capacity.

*Rail*

The most visible emerging technologies in the railway industry are modifications to existing vehicles and next generation locomotives. In both cases these developments essentially replace the emergent technologies of 25 years ago. Examples are illustrated in Table 3. Control of unmanned trains is readily available, although implementation has faced hurdles with respect to safety, labour relations and financing. In addition, within the realm of automatic train control, the operational priority has shifted from ground control to in-vehicle control systems.\(^2\)
**Trucking**

Emerging truck technologies involve continued changes to vehicle size and engine efficiency. Significantly, many of the most economically important technology implementations do not involve the physical vehicles themselves, but rather involve navigation and communication technologies that allow improved service to customers.

**Intermodal**

Intermodal technology refers to the transport of goods by two or more modes of transportation:

1. Internationally in standardized *marine containers* by vessel with transfers to rail and truck.

2. Domestically (within North America) in trailer-on-flat-car (TOFC) or container-on-flat-car (COFC) by a combination of rail and truck. Domestic “boxes” are not the same as those involved in liner shipping and are manufactured by trailer manufacturers.

The Road Map pertains only to the *domestic portions* of these movements, involving truck pick-up and delivery, rail line haul movement, and truck-rail transfers.

Both types of intermodal equipment have been around since the 1950s. Since then they have been heralded as having the potential to revolutionize freight transportation services. More recent modifications to original intermodal equipment have focused on reducing the time and cost involved in truck-rail transfers, in simplifying the loading and unloading of units, and adding capacity. Canada’s two Class I railways (CN and CP) have worked with equipment developers and continue to search for a more “seamless” intermodal vehicle. To date developments include:

- “carless” technology, or hybrid road-rail vehicles (e.g. *RoadRailer, EcoRail*);
- more efficient and sophisticated handling equipment (e.g. cranes);
- double-stack container cars.
### Table 1: Emerging Technologies in Freight Transportation Services

<table>
<thead>
<tr>
<th>Technology Category</th>
<th>Technology Sub-Category</th>
<th>Examples</th>
<th>Impact/Oportunity</th>
</tr>
</thead>
</table>
| **Marine**          | Propulsion Systems      | Advanced Engines | • Diesel engines  
• Ceramic engines  
• Electronic engine control | • Improved fuel efficiency  
• Longer lasting engines |
|                     | Information Technology & Communications | Navigation | • GPS  
• On-board navigation  
• Vessel control systems | • Reduced labour costs  
• Improved safety  
• Reduced transit times |
| **Rail**            | Propulsion Systems      | Advanced Engines | • Next generation diesel/electric locomotives (alternating current traction) | • More haulage capacity;  
• Lower operating and capital costs (higher powered, more efficient) |
|                     | Vehicle Design & Manufacture | Advanced Vehicle Design/Advanced Materials | • Light weight alloys in freight cars and rails. | • More load capacity  
• More cars per train |
| **Trucking**        | Propulsion Systems      | Advanced Engines | • Ceramic engines  
• Electronic engine control  
• Lean-burn motors | • Improved fuel efficiency  
• Lower emissions |
|                     | Vehicle Design & Manufacture | Advanced Vehicle Design/Advanced Materials | • Streamlined design  
• Active suspensions  
• Longer, lighter trailers | • Improved vehicle dynamics(fuel efficiency)  
• More load capacity  
• Less road damage  
• Safer |
| **Intermodal**      | Vehicle Design & Manufacture | Advanced Vehicle Design/Advanced Materials | • Carless vehicles: Road Railer, EcoRail, Iron Highway  
• Containers  
• Double-stack containers | • Improved capacity  
• Rail/Road competition  
• Value-added freight |
Enabling Technologies

The following section presents enabling technologies for the freight transportation services industry. Developing new technologies in areas such as information and telecommunications and sustainable transportation technologies can be very expensive and require a broad range of expertise. Some of these technologies are already commercialized but many cannot be from options offer the promise of meeting both increasingly forceful shipper demands for improved service. The first part identifies technologies required to meet medium-term market/service demands.

Information and Telecommunications Technology: Types

There are six major types of information and telecommunications technologies that are available for use in the freight transportation industry. They are often combined together to create new technology applications for the industry.

Electronic Data Interchange—EDI

EDI is the computer-to-computer exchange of data by businesses in a standardized electronic form. It enables shippers, carriers and related parties to communicate efficiently via an electronic medium, enabling the operation of a seamless transportation system. EDI facilitates the movement of goods from initial customer request through equipment supply/pickup and cargo handling by carriers to ultimate destination and customer (including invoicing, documentation and financial transactions). The major benefits of EDI for freight transportation are that it minimizes manual data entry, increases transaction speed, increases accuracy, lowers communications costs, enables automatic data processing, promotes simplification of procedures, and increases productivity and efficiency.

Global Positioning Systems—GPS

GPS uses satellites to track in real time the location of vehicles or equipment. Its benefits are enjoyed by shipping companies, trucking companies, railways and others in freight transportation. DGPS (Differential GPS) is a further refinement on GPS that enables greater location accuracy, up to +/- 10 metres. DGPS receivers on board trucks, marine vessels, and railway vehicles enable operators to pinpoint their location very accurately. The precise location and tracking of vehicles, packages and containers benefits transportation companies whose customers want to keep track of where their packages are located. It also allows sophisticated high-density traffic systems to operate safely and efficiently.

Geographic Information Systems—GIS

GIS enables electronic maps to be produced for highway and railway networks. They also provide electronic charts for marine navigation. Unlike conventional maps, electronic maps and...
charts can be integrated with other technology, such as automated equipment identification, to create useful applications such as routing and tracking programs. These are very popular with trucking and courier companies, who depend on the technology to improve their efficiency and safety. Electronic maps can be easily altered and manipulated via the use of computers, enabling more specialized applications to be achieved, e.g. displaying rail car locations in particular corridors. GIS, when combined with other telecommunications technologies, forms an integral component of several transportation applications, including truck routing systems, marine vessel traffic systems, marine navigation systems, and intermodal cargo tracking. GIS provides for route and trip planning potential when integrated with real time traffic monitoring systems and allows for greater operating efficiency and reduced idle time, by increasing the capacity utilization of vehicles and vessels.

Automatic Equipment Identification—AEI

With AEI systems, transportation equipment (e.g. truck trailers, rail cars and containers) can be equipped with individual electronic transponders. Each transponder has a unique code. The code is detected by an interrogation unit, usually located at terminal gates or at fixed points along the route. Details of vehicles or containers/packages detected by the interrogation units are recorded and/or sent to a central location for data processing. This data can be used in EDI applications, such as customs declarations and fuel tax payments. AEI systems are integral to tracking and positioning systems employed by container port operators, trucking companies, couriers and railway companies.

Mobile Communications—MC

Mobile communications consists of two-way voice and data communications between a moving vehicle and a terminal or ground station. MC technology enables real time transmission of voice or data via radio, cellular and satellite devices. Data can include electronic mail, EDI, and vehicle or cargo monitoring information. For example, a vehicle’s location, operating performance, fuel efficiency, weight and container number can be sent back to the fleet headquarters to analyze driver performance or efficiency of routing decisions. As MC technology is so flexible and available, it is used in all transportation modes and incorporated in most IT technology applications.

Electronic Funds Transfer—EFT

EFT allows for the payment of goods or services electronically. With EFT, funds move between banks and countries safely and securely. Time consuming and wasteful paper documentation is eliminated and the whole transfer process is speeded up. This reduces administrative costs for transportation companies. Starting with the paperless invoice, or electronic request for transportation services, the EFT process complements and closes the loop for commercial transactions in freight transportation. EFT is being incorporated into communications via the Internet. While there are concerns regarding the safety and confidentiality of the transfer process,
security procedures and encryption processes are being developed to fully utilize this communications corridor.

**Information and Telecommunications Technology: Applications**

The types of IT technologies (described above) are being utilized in an enormous array of applications in the freight transportation industry. The most prominent of these technology applications for the freight transportation industry are described below.

**Intelligent Vehicle Systems—IVS**

The concept of Intelligent Vehicle Systems is based on technology enabling vehicles to act “intelligently”. IVS incorporates advanced computer, telecommunications and sensor technologies in vehicles along routes. "Intelligent" vehicles improve the performance of transportation systems by operating in the most technologically proficient and overall efficient manner. Human error is reduced as vehicles are able to respond more quickly to situations or provide instantaneous data feedback for operators. Some of the main IVS applications include: advanced trip planning systems (provides information on preferred routing and optimum travel times), advanced travel conditions systems (provides information on road, traffic and weather conditions), advanced mobile communication systems (provides direct voice and data communication between vehicles and stationary terminals), automatic vehicle identification (identifies passing vehicles based on some form of electronic license plate), weigh-in-motion systems (measures axle and gross vehicle weights for commercial trucks), and advanced assist/control systems (includes monitoring of driver behaviour and vehicle control).

**Traffic Management Systems—TMS**

TMS incorporates IT technologies to promote more efficient use of existing transportation systems. It can increase the safety, mobility and efficiency of vehicles operating within the transportation system by decreasing the environmental impact (improved fuel efficiency, lower emissions, and reduced noise and congestion), improving operational efficiency (reduced down time and improved vehicle and system capacity utilization), and reducing the risk of accident and consequential damage. TMS is used extensively in the trucking, marine and railway modes. Two examples are Intelligent Vehicle Highway Systems (e.g. overhead or roadside changeable message signs, synchronized traffic lights, congestion analysis systems, and electronic tolling) and Vessel Traffic Systems (i.e. to increase safety and efficiency of marine vessel traffic in congested ports or high traffic density restricted waterways, such as the St. Lawrence Seaway).

**Fleet Management Systems—FMS**

FMS is a management tool that enables a truck fleet’s operations to be managed effectively, thereby increasing efficiency and lowering costs. FMS can significantly reduce fuel consumption and emissions. Aside from the environmental benefits of lower emissions, fleet managers have a

*Technology Road Map for Freight Transportation Services*
strong financial incentive to implement fleet management programs to reduce fuel costs. Some of the main FMS applications include: integrated systems (to help control a fleet’s transportation costs and increase its productivity), routing systems (to create optimal pickup and delivery in urban areas or to determine the best long distance routes to utilize), dispatch systems (to communicate immediate shipment or work order information to drivers and trace customer shipments), and onboard monitoring systems (to monitor driving habits, track fuel economy by vehicle, schedule and monitor preventative maintenance, and provide a detailed event history for accident analysis).

**Just-In-Time (JIT) Systems**

JIT is important to logistics processes. It is an inventory replenishment method whereby a company keeps minimal stocks on hand, suppliers deliver only quantities immediately required, and inventories are carried by suppliers as opposed to purchasers. This results in a streamlined and accelerated transportation and distribution process. It requires accurate communications between shippers and carriers, utilizing the latest information and telecommunications technologies. Direct electronic links between suppliers and purchasers enable inventory to be minimized and transportation capacity utilization to be maximized. JIT is used extensively by large manufacturing industries, automobile manufacturers and parts suppliers, major retail suppliers and outlets, and food distributors.

**Tracking Systems**

Satellite tracking systems are an IT technology application that permits carriers, intermediaries and shippers to know precisely where their goods are physically located, often in real time. These systems are used extensively in the trucking industry. The systems consist of onboard terminals and communications software. While single mode tracking is not new, the future challenge lies in multimodal tracking. Some container companies have these systems in place. Outside of the container shipping and courier industries, their use is generally not widespread in the freight transportation industry.

**Positioning Systems**

Similar to tracking systems, positioning systems focus on determining the precise location of objects. These systems are used extensively in the courier and trucking (LTL) business. Their benefits include the following: improved operations management (optimal asset allocation and routing and tracking of assets), improved customer service (rapid and flexible response and enhanced EDI integration), enhanced administrative compliance (customs, fuel tax, inspections, licensing) and improved safety and security.

**Bar Coding**

Bar coding is used by most courier companies and LTL carriers. Combined with tracking and

*Technology Road Map for Freight Transportation Services*
positioning systems, it enables containers, packages and shipments to be tracked through the
distribution system. Shipments are scanned when received and delivered, and at key handling
points. Standard technology includes hand-held reading devices with communications links. The
information can be accessed by shippers or received via their communications systems.

**Electronic Commerce**

The purpose of employing electronic commerce is to create a paperless document flow.
Electronic commerce employs EDI and EFT technology to create a more efficient order/payment
system. Electronic commerce is used by freight transportation companies for invoicing,
manifests, customs, and payments. The primary benefits are that the rapid transmission of orders
and payments reduces the payment period and improves operating margins and that a larger
number of participants receive more accurate and timely information.

**Data Warehousing**

With the advent of bar-coding and point-of-sale information, massive quantities of data are
available to freight transportation companies and their customers. This data is being
“warehoused” and analyzed to identify product flows, trade patterns and container routings, and
to do transportation performance analyses.

**Neural Networks**

Due to inherent fluctuations in travel demand, unpredictable occurrence of traffic incidents, and
change of weather conditions, travel times in urban traffic environments are significantly
dynamic and uncertain in the sense that they change by time of day and cannot be identified with
certainty. In this type of environment, it is important to explicitly consider the dynamic and
uncertain link travel times within vehicle routing frameworks, and the need to develop faster
routing algorithms for real time operation purposes. Research in this area is focused on the
development of heuristic shortest path algorithms and the application of artificial neural
networks. Efforts are also being made to develop and field test a neural network ship predictor
system that will estimate the future position and orientation of ships. The system will be used to
assist ships in maneuvering and docking in confined waterways.

The focus of this research is to maximize the operating efficiency of the vessel, thereby reducing
fuel consumption and emissions. The system combines artificial intelligence technology with
standard maneuvering theory, taking into account the current position of the vessel, the wind and
rudder, and control settings. The work includes the development and coding of maneuvering and
motion algorithms, the creation and testing of the neural network predictor, and the installation
of an electronic navigation system.
Sustainable Transportation Technologies

Sustainable transport technologies fall into three categories: alternative fuel technologies, advanced engine technologies and advanced vehicle technologies.

1. Alternative Fuel Technologies

Advances in alternative fuel technologies have been concentrated on alcohol based fuels, compressed natural gas, liquefied petroleum gas, hydrogen, fuel additives, and batteries/fuel cells. Significant advances are being made in the freight transportation sector for utilizing alternative fuels. Developments in alternative fuel technologies go hand-in-hand with new advanced engine and vehicle technologies. These alternative fuels offer the possibility of fuel savings and efficiencies, as well as reducing significantly the level of emissions.

Alcohol Based Fuels

This focuses on the use of high (>80%) alcohol or ether fuels. Alcohol fuels can be made from sources other than crude oil, and many of the nations that have researched and used alcohol fuels have based their choice on import substitution. Alcohol fuels can burn more efficiently, and can reduce photochemically-active emissions. Most vehicle manufacturers favour the use of liquid fuels over compressed or liquefied gases. The alcohol fuels have high octane ratings, but also high sensitivity and high latent heats. The major advantages are gained when pure fuels are used, as the addition of hydrocarbons to overcome cold start problems reduces any emission benefits. Alcohol based fuels are also used in conjunction with conventional petroleum fuels. While technology is focused passenger vehicles, developments in ethanol and methanol may be utilized in the future in freight transportation.

Compressed Natural Gas (CNG)

CNG is usually around 70-90% methane with 10-30% ethane and propane. It has a high octane and usually only trace quantities of unsaturates. The emissions from CNG have lower concentrations of the hydrocarbons responsible for photochemical smog, reduced CO, SOx and NOx, and the lean misfire limit is extended. There are no technical disadvantages, providing installation is performed correctly. The major disadvantage of CNG is the reduced range. CNG vehicles usually have between one to three cylinders (25 MPa, 90-120 litre capacity), and they usually represent about 50% of the gasoline range. As natural gas pipelines do not go everywhere, most conversions are dual fuel with gasoline. The conversion costs for passenger vehicles are usually around US $1,500, so the economics are very dependent on the price of natural gas. The typical 15% power loss means that driveability of retrofitted CNG fueled vehicles is easily impaired. This limits its use to vehicles that operate in an urban setting. The lack of fuel stations is also a major impediment to its use in long distance freight transportation.
Liquefied Petroleum Gas (LPG)

LPG is predominantly propane. It has one major advantage over CNG, i.e. the tanks do not have to be high pressure and the fuel is stored as a liquid. LPG offers most of the environmental benefits of CNG, including high octane. Approximately 20-25% more fuel is required, unless the engine is optimized for LPG, in which case there is no decrease in power or increase in fuel consumption. Several studies have compared the relative advantages of CNG and LPG, and often LPG has been found to be a more suitable transportation fuel due to its inherent storage characteristics.

Hydrogen

Hydrogen’s characteristics are intriguing, and highlight both its advantages and drawbacks as a fuel. It is the most abundant element in the universe and also the lightest. As one would expect, it occupies a great deal of space per Btu—at atmospheric pressure, 3,000 times more than gasoline—so it is only useful as a fuel in concentrated form. Its high heat generation per volume of air and small ignition energy requirement make it good for lean burn, but a very fast combustion speed (2.7 meter/second vs. gasoline’s 0.38 m/s) translates into a very low octane number. The major advantages of hydrogen are: almost no harmful emissions and no CO$_2$; electricity is generated off-peak and can be converted into a storable, portable, and easily usable gas; and supplies are cheap and readily available. Major disadvantages include: “irregular combustion” (meaning severe pre-ignition, intake backfire and detonation, when used in an unmodified piston engine); storage and handling problems (at atmospheric pressure, it takes over three cubic yards to store the same energy as in one quart of gasoline); and supply outlets (a major switch to hydrogen fuel would require a new energy supply infrastructure).

Fuel Additives

Fuel additives are widely used in the automobile and trucking sectors to increase operating efficiencies and reduce the overall level of emissions. Current developments are being made to utilize additives to reduce engine wear as well as optimize the fuel burn cycle. Fuel additives have come under scrutiny due to their inherent toxicity and the potential impact on the environment. However, overall they offer an inexpensive and easily adaptable method to improve the output of current engine designs. Most after-market fuel additives take the shape of pills, tablets, magnets or filters that claim to improve either fuel economy or performance. Most of them have sound scientific mechanisms but not all of them are cost effective.

Batteries And Fuel Cells

Significant developments in battery and fuel cell technology have resulted from numerous research and development activities being carried out in Europe and North America. Battery research has focused on improving the efficiency of conventional lead acid batteries, as well as developing usable nickel cadmium and zinc air batteries. The latter offers exceptional potential,
as it delivers the most power for its size and weight. Fuel cell technology offers the potential for emission-free transportation, due to the overall efficiencies of burning only hydrogen and oxygen. Research in this area is being carried out by Ballard Power Systems of Burnaby, B.C.

A fuel cell differs from a traditional battery in several ways. A battery is an energy storage device; the amount of electrical energy that is available is dependent on the mass of chemical reactant stored in the battery. When the reactants are fully consumed (discharged) the battery must be recharged before it is useful again. A fuel cell is an energy conversion device; no fuel cell component is consumed with the reaction. As a result, a fuel cell is able to produce electricity as long as reactants are provided. Because the fuel cell transforms the fuel directly into electricity without combustion, there is little waste heat and a very high rate of chemical to electrical energy conversion. The construction of a fuel cell is similar to a battery, except that it does not undergo a material change and consequently operates as long as fuel and air are available.

2. Advanced Engine Technologies

Developments in advanced engine technologies are being made in several areas, including: flywheel and lean burn designs, direct fuel injection, electric/hybrid designs, transmissions, waterjet propulsion, and engine control systems.

*Flywheel Engines*

The flywheel engine design, as a concept, has been available for many years. New developments are making it one of the leading radical engine designs of the decade. Flywheel research involves developing a propulsion system that is, in theory, more powerful, more fuel efficient and less polluting than an internal combustion engine. It employs two power sources—a small turbogenerator and a carbon-fibre flywheel to run electric motors that drive the wheels of a vehicle. To power the motors that turn the wheels, there is a turbine engine that generates roughly 60 HP—just enough to maintain a vehicle’s speed on relatively flat stretches. Because the turbines utilize a lean fuel air mixture that burns at a lower temperature, most of the noxious chemicals that contribute to smog do not clog the exhaust system. For improved performance, the turbogenerator is coupled with the flywheel. It spins silently at very high speed inside a vacuum chamber. Flywheels were conceived to both produce and store energy. When the vehicle is cruising or braking, extra energy is transferred to the flywheel, increasing its rotation speed. Conversely, when more power is needed, the fly wheel switches to being a generator and produces 150 kw or 200 HP. Currently, the technology is being developed for passenger cars and small utility vehicles. Eventually, flywheel technology could be applied to larger vehicles, such as delivery vehicles and trucks.

*Direct Fuel Injection*

Developments in fuel injection systems are being made, imitating current diesel technology.

*Technology Road Map for Freight Transportation Services*
Direct fuel injection promises greater control of how the fuel is squirted into the cylinder and thus provides a way for making sure that all the fuel is properly burned on each cycle stroke. In return, that means that less fuel is wasted and fewer exhaust pollutants are produced in the process. With direct fuel injection, the fuel vaporizes before it can disperse. The result is a wad of easily ignitable air-fuel mixture being tumbled around in a vortex of otherwise unburnable gas. When the impregnated wad circulates to the top of the cylinder, the spark plug fires and the flame heats up the rest of the weak air-fuel mixture sufficiently for it too to start burning. The net result of this process is a peak temperature in the cylinder; that is low enough to inhibit production of nitrogen oxides, while the average temperature is high enough to restrict the amount of carbon monoxide and unburned hydrocarbons produced. The boost in power afforded by this system results from injecting the fuel into the engines cylinders directly. This technology is focused on passenger transportation, as it involves the use of gasoline engines. However, these engines could be employed in short haul freight operations such as delivery trucks.

**Lean Burn Truck Engines**

Lean burn engine technology is at the forefront of much of the new developments in truck engine research. Lean burn technology relies on a higher air-to-fuel ratio for more efficient engine performance and reduced levels of emissions. The new truck engines utilize spark-ignited six cylinder engines with lean burn technology to provide cooler combustion temperatures and reduced levels of nitrous oxides and increased engine durability. The lean burn air-to-fuel mix also results in more complete conversion of fuel to energy and a greater percentage of the fuel’s potential energy being released during combustion, an indicator known as thermal efficiency. Early experience with lean burn production engines for truck and bus fleets has allowed engine makers and truck producers to respond quickly to new developments. Recent advances in lean burn technology have maintained diesel-like performance, reliability and durability standards, while utilizing less polluting types of alternative fuels.

**Waterjet Propulsion**

Progressive growth in the power ratings of waterjet systems—until recently confined to leisure water craft and military ships—has been stimulated by new generations of high speed marine vessels. Installations embracing two, three and four waterjet units, in fully steerable/reversible or booster versions, offer flexible propulsion machinery arrangements marrying speed with fuel economy. Special merits cited by waterjet designers over propellers include better fuel economy, reduced internal noise, improved maneuverability over the entire speed range, insensitivity to debris in the water, and good acceleration with outstanding crash stop capability. Cost-saving machinery layouts are also fostered by eliminating reversing gear sets and long transmission lines. While fuel consumption is quite high, increasing demands for high speed vessels for short haul freight ferries will probably foster further developments in this engine technology. It offers improved emissions over conventional diesel engines and can be adapted to meet possible future stringent emissions legislation.
Hybrid Electric Power Systems

Turbogenerator research is underway to develop low polluting auxiliary power systems for hybrid electric vehicles. The research could result in a 50 kw turbogenerator with dual use applications, concentrated on the military and commercial freight markets. Advancements in the turbogenerator include the use of air bearings, which eliminate the need for oil or other lubricants. Furthermore, the generator is built into the shaft and rotates at the same speed as the shaft, so that there is no gearbox, which eliminates a considerable number of moving parts. The unit is designed to meet the needs of hybrid electric vehicles, which must be low cost, compact and quiet. The vehicles must also produce little if any exhaust emissions, consume little fuel and exhibit high reliability. Developments in turbocharger technology are key for extending the range and efficiency of hybrid electric vehicles.

Continuously Variable Transmissions (CVT)

CVTs provide an unlimited number of gear ratios instead of the 3, 4 or 5 gears that conventional transmissions offer. The concept has been around for a long time but new developments in this area have been spurred by more stringent emissions legislation, which are forcing engineers to consider the inherent efficiency advantages of an engine that operates within a narrow band of speeds—a trait that could make CVTs commercially feasible. The ability to adjust the gear ratio along a smooth continuum rather than in discrete steps improves overall efficiency because the engine can operate steadily at its optimal speed rather than intermittently revving up and slowing down—the fuel wasting procedure that conventional transmissions require. Thus, drivetrains with CVTs offer better fuel economy than those operating with conventional gear boxes. CVTs are currently installed in more than one million cars worldwide. The technology is being adapted for heavy vehicle use, which can best capture the fuel savings associated with the technology when applied to diesel engines. CVTs offer one of the best immediate forms of fuel reduction, while maintaining overall operating and commercial efficiencies.

Engine Control Systems

Engine control systems utilize advanced microprocessor technology to analyze and monitor engine performance. The systems allow for the optimal operation of engines, automatically adjusting engine operations to optimize fuel efficiency and reduce overall emissions. Engine control systems are used primarily in truck, rail and marine vessel engines. Engine control systems have been developed which monitor the following engine activities: engine oil pressure, coolant pressure, wet battery current, transmission oil pressure, injection cylinders, glow plug relay, fuel delivery pressure, boost pressure, turbo oil pressure, engine coolant temperature, alternator current, injector control pressure and refrigerant pressure.

Selective Catalytic Reduction (SCR):

Research is underway to analyze the feasibility of reducing NOx emissions from heavy-duty
Engines by using selective catalytic reduction. Commonly used with stationary emission sources, SCR introduces ammonia into the exhaust stream where, when passed over a catalyst, it selectively reduces NO\textsubscript{x}. Adaptation of the technology to a mobile, transient emission source involves the development of a computer-controlled ammonia injection system that can accurately meter gaseous ammonia into the exhaust stream, taking into account engine operating conditions and catalyst temperature requirements.

3. Advanced Vehicle Technologies

Advanced vehicle technologies include research and development into redesigning or developing new vehicles or vessels. Developments in the marine mode have been concentrated on designing larger and faster vessels. Developments in rail technology have been concentrated on making more effective use of rail car designs for increasing the efficiencies of intermodal activities. Truck research has focused on designing more efficient trailers, as opposed to radically altering the overall design of the vehicles.

*Marine Vessels*

- **Bulk Vessels.** There is a growing trend towards the employment of large vessels in bulk shipping. Very large bulk carriers have been in existence for the past ten years, and it appears that the maximum commercially feasible size for vessels has been reached. Panamax vessels with a dwt capacity of 55,000 tonnes are the work horse of the international bulk fleet. Cape-size vessels up to 300,000 dwt tonnes are used predominantly in the iron ore and coal trades. The benefits of large size vessels are their increased capacity and lower operating costs per tonne kilometre transported.

- **Container Vessels.** The size of container vessels has increased dramatically in recent years. Where 2500 TEU vessels were the norm in 1993, new vessels are in excess of 6000 TEUs, with larger vessels up to 8000 TEUs in various stages of design. These larger vessels increase the efficiency of the transportation system, reducing the overall energy required to transport a container.

- **Fast Ships.** Fast Ship technology is employed by cargo ships that are capable of travelling at speeds up to 40 knots. They employ huge gas turbine engines capable of delivering up to 400,000 HP. They do not employ propellers, since conventional propulsion technology cannot achieve these speeds. These vessels are currently in the development stage.

- **Fast Ferries.** Ferry technology has advanced recently with the advent of high speed ferries. The main features of new fast ferries are as follows: continuous service speeds of up to 44 knots; twin hull construction to increase carrying capacity; light-weight aluminum and composites used to increase speed and capacity; advanced hull design to enable operations in rough weather; watertight sub-compartments to reduce the impact of
collisions or strikings; increased soundproofing and noise reduction technology; and advanced environmental control systems.

**Rail Vehicles**

- **Iron Highway.** This system was pioneered by CSX Intermodal for its intermodal activities in the U.S. The iron highway system employs small, specially designed locomotives located at each end of a string of 1,200-foot articulated platforms that divide in the middle to form ramps for loading/unloading of regular truck trailers. Commercial service in Canada was introduced on the Montreal-Toronto corridor.

- **Ecorail.** This concept was developed by Quebec-based Innotermodal Inc., with backing from CN. The system employs smaller, more efficient motive power to haul containers over the short to medium distance. Each power unit can pull a convoy of up to 10 trailers, which can operate individually or in combination to form longer trains. The trailers are ordinary truck trailers that have been modified to be hitched onto specially designed rail bogies. This concept permits shorter train lengths allowing for greater service frequency. It also avoids the use of expensive terminal handling equipment.

- **Railrunner.** This technology is based on an independent detachable bogie to which modified highway trailers of any sort are pinned at either end. The main difference with other systems is that the bogies have air-ride suspension for reduced freight damage and less stress on the trailer, along with radial steering, which allows higher speeds. The system also uses ordinary locomotive power. The key advantage to the system is that a trailer can be loaded onto the train anywhere without elaborate and expensive lifting systems.

- **Roadrailer.** Roadrailer uses conventional locomotives and reinforced trailers for its operation. However, it must assemble longer train lengths, up to 70 trailers, to obtain the necessary operating economies. The system reduces line-haul costs because reinforced trailers are pulled directly by a locomotive. There is also no need for rail flat cars or elaborate handling equipment at terminals. The system does incur delays due to trailer assembly/disassembly at terminals. It is capable of being service-competitive in the 500-mile range.

- **Double-Stacking.** The ability to double stack containers dramatically increases the efficiency of intermodal movements. It reduces rail line-haul costs due to the inherent economics of double stacking containers and the use of articulated rail cars. In Canada, it is enhanced by the development of the new tunnel at Sarnia, capable of allowing double-stack cars with 9 ft. 6 in. containers to move directly to Midwest points.

**Truck Vehicles**

Research is being undertaken to develop a reduced weight tractor-trailer that will result in
savings to operators by allowing them to transport more cargo using less fuel. It involves the use of advanced materials and construction designs for weight saving potential, cost and suitability for the freight transportation system. Vehicle dynamics simulation software is used to approximate flexing and stresses at critical points, to model suspension response to road forces, and to estimate the durability of semi-trailer designs. Research is also underway to more accurately measure vehicle dynamic loads at highway speeds, and the roll stability and roll response characteristics of fully-loaded vehicles. This will result in improved vehicle design specifications.

- **Advanced Materials.** Research and development in advanced materials is wide in scope. For the freight transportation industry, efforts are focused on decreasing the weight of vehicles through materials that provide strength through design and rigidity as opposed to material weight. Specific areas of investigation include: development of steel alloys and sandwich construction to reduce vehicle weight and improve strength of trailer panels; development of aluminum alloys for reduced hull weight for fast ships and fast ferries; increased use of aluminum alloys in engine and chassis construction to reduce weight; use of rigid steel in rail car manufacturing to improve chassis strength and reduce tare weight; and use of plastic and carbon products for trailers and rail cars.

**IMPLEMENTATION ISSUES AND OPTIONS**

This section presents the results from the Technology Workshop held in Winnipeg in September 1997. In addition to addressing implementation issues and developing an action plan, the Workshop served as a starting point for creating technology transfer and technology partnerships.

Defining the specific concerns of stakeholders began with Industry Focus Groups and were refined further at a Technology Workshop. The major objectives were to discuss issues that confront the adoption and implementation of new technologies in the freight transportation sector and identify the various options available for overcoming obstacles and encouraging technological innovation in the industry.

Implementation issues/options, therefore, cover a wide range of concerns, including:

- the general economic environment;
- the costs and risks of technology development and acquisition (and who should bear them);
- the regulatory framework which facilitates or hinders innovation, and
- education and training.

These concerns are not necessarily confined to the medium-term time frame of the Technology Roadmap. They cover a range of issues from the short-term concerns of carriers and equipment suppliers driven by tight profit margins and financial constraints, to the long-term developmental

*Technology Road Map for Freight Transportation Services*
goals of research communities, including government agencies. The Workshop had the following goals:

- To identify and define the key concerns of various stakeholders.
- To assess the various options available for overcoming the issues to the best satisfaction of all.
- To develop a strategic action plan for implementation.

**Issues**

The freight transportation industry is large, disparate, and complex in scale and scope. The development of transport systems is characterized by long periods of incremental improvements to existing technology and relatively infrequent breakthroughs in components or processes. Consequently, technological innovation and related R&D cannot be considered “discretionary” items. They involve thorough investigations of numerous technical and operational questions or problems, many unknown phenomena and crucial safety issues. New technology cannot be put into practice (that is in revenue service) until all of these questions are answered to the full satisfaction of all those concerned, including the public.

**Innovative Process**

The innovative process requires significant inputs of R&D resources without guarantees of commercial returns. In other words, it is characterized by a high degree of risk. However, R&D remains a fundamental condition for innovation to reach the pay-off stage. This technology paradox is the central problem facing technology managers. Technology management in transportation involves, therefore, striking a balance between continued concentration on conventional technologies and diverting effort toward bringing in new technology.

Successful completion of an innovation cycle depends as much on technological successes at all stages of the innovation cycle (technical risk), as on the availability of steeply rising resources and continued commitment (capital risk) from a diverse set of stakeholders over an indeterminate length of time. The risk capital required to create and sustain this effort does not appear to be available under commercial terms in Canada. Classical venture capital models are insufficient. As a consequence, government participation is essential.

Technological innovation in transportation requires a combined approach, involving public and private support for R&D efforts in a coordinated fashion. The key elements of this approach are illustrated in Figure 1.

The pure research elements of the equation — science and engineering — depend mainly on governments in the form of direct or indirect support. A substantial portion of this support comes in the form of educational institutions such as universities that perform critical exploratory research that would be deemed too risky by the private sector.

*Technology Road Map for Freight Transportation Services*
Research of this kind can be made more effective, however, when it overlaps with private support. Private involvement can help target applied technologies. At the same time, the level of private support is dependent on government policy. Negative incentives, such as regulations and taxation, can limit private support. On the other hand, government policies that encourage competition or provide tax breaks can elicit stronger private support for research. The combination of the three elements determines the level of technological innovation or advance.

**R&D Funding Policy and Approach**

The situation of transportation R&D has been well documented by other studies and so is not reproduced here. Instead, the following summary remarks can be made:

**Investment**

The total transportation R&D effort in Canada, as a percentage of the total transportation cost, is lower than the global GDP average. Consequently, transportation in Canada ranks lower than average in innovation or technology intensiveness among other industrial sectors. This would seem out of proportion with the impact the industry has on the national economy.

**Research Priorities**

While the private sector carries an important proportion of this total R&D effort, the objectives of it are not generally set to serve national transportation system priorities. In the main they are...
set (quite understandably) by corporate priorities. Naturally private sector research is proprietary and confidential.

Existing Programs

The transportation R&D programs directly sponsored by governments derive from institutional or jurisdictional divisions and correlate strongly with existing modal segments. These programs cover an immense range of activities, involving diverse technologies, and develop simultaneously. Coordination of them within a public and private consultative framework is difficult even when pursued.

Communication

Most failures or delays in transportation development are not always the result of lack of funds per se, but are often due to poor communications and understanding between those promoting the innovation, those regulating the process, the end users and the public sectors affected.

In sum, innovation in transportation in Canada has been an exercise in the art of the possible, satisfying modal users and niche markets. Given the objectives of the Road Map, much The remainder of this section addresses the issues raised by these summary points.

Options

R&D

This section addresses issues related to technological innovation and associated R&D. It does not address strategic R&D needs, but rather issues related to implementation of current and future technologies. The point of view taken is that the problems with and needs of Canadian transportation are not primarily technical in nature. The history of transportation, and of the innovative process generally, indicates that technical “fixes” for system inefficiencies are infrequent. Moreover, they do not necessarily receive successful implementation. Recent research on innovation indicates that the reasons for this lag lie not with exogenous (that is unexplained) technical factors. It is primarily endogenous factors — economic decisions of firms, management and organization, communication and knowledge sharing, and education and training — that delay implementation.

- Establish and support collaborative pre-competitive public/private sector research consortiums in transportation.
- Foster quicker, more effective, dissemination of scientific and technical knowledge between government and business research agencies.
- Continue to promote R & D through incentive programs (tax incentives, loan guarantees, etc.)
- Foster more R & D within the private sector

Technology Road Map for Freight Transportation Services
• Enhance 'Centers of Excellence' and other export network for Transportation
• Do better exploitation of existing technologies
• Review the role of the transportation Development Centre (TDC)
• Enhance and formalize the scientific intelligence program
• Encourage more private sector R & D by improving tax incentive payback ratio (e.g. 1:2)
• Examine the problems associated with proprietary rights of R & D in the transportation sector
• Encourage transportation technology firms at University 'smart' parks
• Participate in International programs that promote technology transfer (i.e. job exchange, symposia)
• Develop a framework to set priorities for Canadian R & D within world mandates (shared R & D within supply chain) (risk-sharing partnerships)

Education, Training, Human Resources Development

• Increase and promote apprenticeship, internship programs based on new technologies and practices
• Increase opportunities for education and training to improve transportation industry technology
• Tax incentives to encourage companies to initiate training
• Establish vocational and professional standards within the industry
• Actively promote careers in transportation technology
• Ensure post secondary transportation program curricula include training in the most current relative technology

Financing

• Encourage investment in R & D through financial risk sharing between government and investors
• Establish faster depreciation rates to encourage new technology adoption
• More intensive lobbying to apply tax revenues from transportation back to transportation sector (i.e. dedicated taxes)
• Encourage more public/private partnerships i.e. ("Boot“-Build, Own Operate, Transfer)-projects, (e.g. Confederation Bridge)
• Encourage use of venture capital in technological advances
• Encourage the visibility and participation of Canadians in the national and international transportation standards setting process
• Identify technology areas of competitive advantage for Canadians
• Rationalize national tax structures to meet the competitive international marketplace (i.e. attract capital)
• Revise existing tax and other incentive schemes

Technology Road Map for Freight Transportation Services
- Encourage industry to establish a check-off for funds for technology development

**Business Climate/Economic Environment**

- Create a level playing field between modes for transportation industry (i.e. through user-pay schemes, dedicated taxes)
- Remove unfair taxation Measures that hurt competition (i.e. property taxes, fuel taxes)
- Streamline the competitive environment by removing barriers to international and domestic trade and domestic entry
- Reduce government control of strategic industries e.g. CWB
- Foster the development of electronic markets for the transportation of freight
- Assist non-collusive cooperation among firms (i.e. cooperation on benchmarking, R&D, commercialization)

**Recommended Action Plans**

The TRM is to provide strategic guidance to both industry and government with the intent of resolving difficulties in the innovation process and fostering new technology partnerships. It does so, however, within the context of a mature industry noted for its resistant to change. The transport world is dominated by diverse communities pursuing well-entrenched and relatively narrow sectoral and modal agendas, albeit for very sensible economic and political reasons. The modal social communities, bound by a common interest in asset use, constitute powerful stabilizing forces for the status quo.

A number of paths were considered in meeting these challenges. Many of the issues in the previous sub-section are interrelated and speak simultaneously to one or more of the issue areas. This is a strong indication that coordinated action is a prerequisite for further progress in any one area. Moreover, other more general issues — with respect to the problems of communication and information sharing among stakeholders — surround and complicate issues such as R&D and funding. In such a situation, the need for technology leadership and industry champions becomes paramount. In particular, two items should have priority, creating new approaches to R&D and fostering an economic environment for innovation in the industry.

**Creating New Approaches to R&D**

Given Canada’s transportation R&D deficit vis-à-vis other industrialized countries, incremental adjustments to public and private funding levels and approaches are insufficient. A departure from current practices, which date from when Canada’s economy was centered almost exclusively on resource exploitation, is required.

- Encourage R&D investment through financial risk sharing arrangements between government and private sector investors.
• Establish and support pre-competitive (public/private) research consortiums in transportation.
• Develop faster, more effective dissemination of scientific and technical knowledge between public (government) and private (business).

Creating an Environment that Fosters Innovation

The transportation industry is still emerging from the shadows of economic regulation, which created economic distortions in the market. The effects of these distortions are still being felt. This issue relates primarily to competitiveness between different modes of transport which drives technological innovation. Government regulation affects all stages of the innovative cycle, from financing options to harmonization of standards. Government regulation can also provide the incentives for innovative activity.

• Create level playing field between transportation modes, through the removal of unfair taxation measures and use of dedicated taxes.
• Remove barriers to international and domestic trade and domestic entry.
• Harmonize North American surface transport regulations such as weights and measures.
• Allow faster depreciation rates to encourage technology adoption.
• Increase and promote apprenticeship and internship programs under public/private partnerships.
• Create more incentive programs for R&D (examples: tax incentives, loan guarantees)
In the left portion of the diagram, a distinction is made between material flow, the transport system (operation), and the traffic system (infrastructure). They are linked by the transport market and the traffic market.

1. **Material Flow.** Manufacturing activities and trade generate demand for moving goods and materials among nodes in the supply chain. This demand can be aggregated and constitutes the total demand for freight transport services.

2. **Transport Operations.** The activities of transport services generate a flow of transport units between nodes, i.e. the transport system. This can be thought of as the “mobile” component of transportation supply.

3. **Transport Infrastructure.** Moving transport units by road, rail or ship requires traffic capacity, which is provided by actual physical infrastructure (roads, ports, etc), and its management (e.g. regulations regarding vehicle sizes, speeds, etc). This is the “immobile” component of the transportation supply.

In the right portion of the diagram similar distinctions are made for information technology and communications.

4. **Information Operations.** Each of the three layers in the transport model requires information in order to efficiently plan its operations. Information generated requires transportation and handling; this is done by information operators operating in the information market. This is the “mobile” component of information supply.

5. **Telecommunications Infrastructure.** The flow of information requires the existence of telecommunications infrastructure in order to exchange this information. The supply and demand for telecommunication services is provided in the telecommunications market, where efficiencies are measured by the degree of customer satisfaction achieved. This is the “immobile” component of the information supply.
NOTES
