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Conceptual Framework for a Technology Map of the Freight Transportation Industry

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Introduction

This paper develops a conceptual framework for a Technology Map of the freight transportation industry. Technology "roadmapping" is defined as "technology forecasting in a decision-making context." As such, it is considered to be a pragmatic and flexible planning tool for identifying the critical enabling technologies required by industry in a rapidly changing economic environment.[1] While technology roadmapping embraces recently rediscovered alternatives to traditional technology forecasting, such as scenario analysis, it is still in need of further elaboration.[2]

The freight transportation industry is uniquely sensitive to market demands. Indeed, decisions governing freight movements are almost automatic consequences of decisions in the production and consumption side of other sectors of the economy.[3] Consequently, the first section of the paper illustrates transportation's place in the macro-economy, and in the technology market; it identifies the key market "drivers" determining freight transport demand. Subsequently, the process of transport technology evolution is described with respect to change over time. The final section outlines a mapping model suitable for assessing the present and future positioning of key technologies.

Transportation Demand and the Technology Market

Transportation usage strongly reflects the circumstances of the underlying socioeconomic and political environment. The freight transportation industry is substantially determined by those factors relating to foreign markets in two ways. First, exports of raw materials reflect overseas demand and are price sensitive because of global supply competitiveness. Second, manufactured goods have several transportation alternatives to choose from, but require competitive service quality. [4]

Demand for transportation is also strongly affected by changing North American trade patterns. In Canada, the shift of service from traditional east-west movements to north-south movements has encouraged motor carriers and the two national railways (CN North America, CP Rail System) to expand cross-border operations. In order to serve existing and new customers successfully, carriers have had to improve their productivity and service. NAFTA, which includes notable provisions for transportation services, and other trade developments such as "Open Skies," constitute a significant market pull. Changes to Canadian transportation policy have intensified the impact of changing trade patterns. Four pieces of legislation - the *National Transportation Act, 1987,* the *Motor Vehicle Transport Act (MVTA)* 1987, "Open Skies," and the new *Canada Transportation Act* (Bill C-14) - have encouraged competition within Canada and its transborder market.

As a result of these internal and external competitive forces, manufacturers, retailers and shippers have re-engineered their supply and distribution chains. They recognize the importance of a highly efficient and effective logistics system. And, given that transportation is so critical in the total logistics chain, businesses are forcibly demanding freight services that emphasize least cost *and* improved customer service. In the new regulatory and globalized environment, business has the option of acquiring goods abroad through cost-effective overseas production, coupled with innovative "logistics management" techniques. Just-In-Time (JIT) inventory systems, Manufacturing

Resource Planning (MRP), and the "Total Cost" Concept are guiding the efforts to re-engineer business logistics.[5] As a result, the ability of transportation firms to adopt new technology has seldom been as important, and is a critical factor in industrial competitiveness.

Figure 1 illustrates the interface between transportation demand and the technology market. In a basic macroeconomic model consisting of: households, or consumers (demand side), and manufacturing firms (supply side) -- and the markets through which they interact (the resource and product markets) -- transportation firms provide an *intermediary* service that makes possible the flow of goods. Again, this is a reflection of the derived nature of the demand for transportation services.

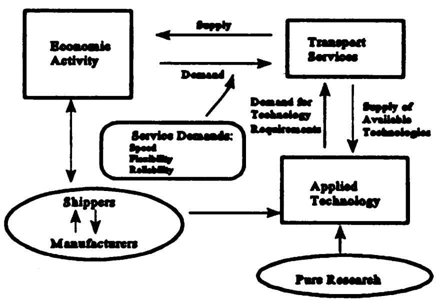

Figure 1 Transport Demand and the Technology Market

A portion of the revenue derived is supplied to the resource market, directly or indirectly through the public sector, where it is used by manufacturing firms in the form of research and development (R&D). R&D is transformed, through the technology market, into feasible technology utilized by transportation firms. A portion of the revenue earned by the transportation firms is used to pay for the R&D costs incurred in the development of technology. Income created from R&D will, technically, go to specific firms engaged in R&D and manufacturing to be distributed by them back to the households.

The service demands of shippers and manufacturers also drive the demand for transportation services. This has implications for technology adoption. To the extent that businesses demand ever-better transport services, transportation firms will respond by demanding technological improvements that lead to an improvement in the quality of transport provided. All else being equal, the need for greater speed, flexibility and reliability of transport, feeds R&D into technological improvements; fulfillment of shipper needs in turn adds to economic growth and thus to further demands for improved transport services. Technological innovation in transportation is, of course, highly dependent on scientific advance ("pure research"). While the private sector contributes to pure research, the majority of these efforts are funded through public institutions, like universities. In reality, the distance between scientific research and the development of applied technology, is greater than that which is implied in Figure 1.[6]

Transportation Technology Evolution and Adoption

General processes govern the invention and introduction of transport technology and the evolution of transport systems. For most of the history of civilization, modes of travel and transport typically involved many or all modes of movement - what we would now call intermodalism. With the introduction of fuel-powered vehicles the modern *modes* of transportation emerged, as commercial operator industries developed to provide modally-oriented service. In general terms, this process is characterized by the invention of new concept vehicles which have evolved into fully-developed (i.e., with supporting infrastructure) modal systems.

Vehicle technology has been the driving force in transport system evolution. Engineering advances were adopted because they permitted higher performance: they were faster and had greater capacity. In its modal character, the modern transportation system has focused on achieving these higher performance measures on *portions* of the total movement of goods, whether it be from origin to terminal, terminal to line-haul, or terminal to destination.

The relatively recent focus on "seamless" intermodal transport, arises in large part from new concerns with *service;* the recognition that from a shipper's perspective the mode of transport is less relevant than issues of comfort, convenience, cost, safety, and timeliness. Put another way, 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.

Life Cycles

The process of system evolution (and the constraints upon it), beginning with the introduction of new concept vehicles, is measured over several decades. The life cycle of the applied technology can be expressed in terms of four stages: (i) Introduction; (ii) Growth and diversification; (iii) Maturity; (iv) Decline. (Figure 2).

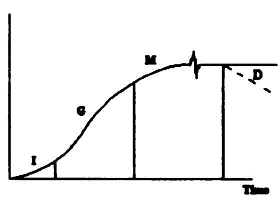

Figure 2 Technology Maturation Sequence

New technology concepts meet market demands because they generally follow a course of rapidly declining cost and improving performance during initial development, as ideas are tested, refined, and more widely diffused.

During the mature phase, which can be an indeterminate length of time, vehicle product differentiation occurs to meet specialized demands (niches). As a result, a generation of closely-related vehicle types emerge, each with a specific life cycle performance.

Technological progress in both design and manufacturing processes over the life of the vehicle generally ensures that the replacement vehicle will be marginally better than the one being replaced. At times major improvements in vehicle performance can be triggered by advances in one or more subsystems; for example, the introduction of the jet turbine engine and the diesel-electric locomotive. Major innovations effect larger system-wide changes, including the manufacturing processes required for commercialisation of the end-product. The entire evolutionary process generates a new generation of modal vehicles, thereby extending the life cycle of the mode.

With the evolution of vehicle type and number, the emphasis on the system as a whole broadens to include the evolution of *road or guide ways*, as they have large relative costs and take substantially longer to plan and acquire. Eventually, however, the impediments to further growth in road and guide ways set in, invoking congestion effects in the system. In economic terms, growth in demand for infrastructure capacity outstrips investment in new capacity. As this occurs emphasis on *control* of the traffic on the system ascends to primary importance.[7] Congestion also exerts pressures in all modes to increase vehicle size and range.

In sum, the evolution of the modern modally-oriented transport system is characterised by gradual evolutionary improvements. In terms of specific technology areas, it is useful to categorize them as follows: *vehicle design and manufacture, propulsion systems, road and guide ways (infrastructure)* and *control systems*.

Given this evolutionary process, it is likely a delusion to look for technological change in terms of quantum leaps, rather than as steady and relatively unspectacular progress. This is confirmed when one looks at the *current*, or existing technology base for freight transport, which is rooted in developments in intermodal transport during the 1950s. While periodic improvements to existing intermodal hardware continue to make intermodal a growth area, the relative absence of technological innovation is part of the reason some industry leaders see intermodal as "a flawed masterpiece." [8]

Adoption

Despite the availability of better inputs, many firms continue to operate below the technological production possibility (Figure 3). Simple adoption by all firms of technology that is already proven and available could provide the economy with a significant stimulus. Two main factors seem to contribute to this phenomenon. First, even at lower cost, smaller firms may be unable to adopt available technology. In such a case, these firms may well be subject to the "tyranny of infrastructure."[9] The second factor preventing adoption of existing technology, concerns management of firms, specifically the nature of knowledge diffusion within the firm. The process of adoption of new technologies, or the diffusion process, has received much new attention recently, as has the innovative process generally.[10]

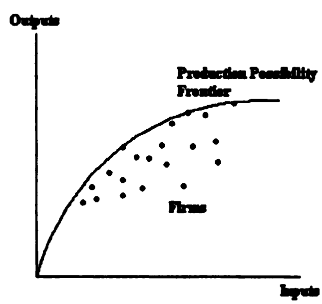

Figure 3 Existing Technology

Figure 4 represents an illustration of the adopter's categories. The Innovators are those businesses that are keen to try any new technology, in the belief that the "first mover" gains are always the largest. The Early Adopters are more conservative, but represent a powerful group of opinion leaders. By the time the Laggards employ the "new" technology it may already be obsolete.

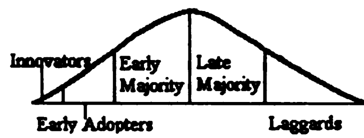

Figure 4 Adopter's Categories

Technology Forecasting, Technology Mapping

It is apparent that technology management is a key responsibility of strategic planners. At the same time, an emerging consensus has found that traditional forecasting methods are inadequate for this purpose, particularly in a rapidly changing economic climate. In its place, scenario analysis offers an attractive alternative because it is better suited to the uncertainties inherent in predicting the future. The purpose of scenario analysis, or scenario planning, is not to focus upon what is likely to happen, but rather upon the *relationships* that will determine what will happen. If used in conjunction with more conventional forecasting techniques (i.e cross-impact analysis), scenario analysis should aid in anticipating and recognizing events that may cause the future to diverge from the most probable "forecast."[11] In this way, it is a flexible planning tool.

Technology roadmaps, in embracing these concepts, have been conceived as "works in progress," in need of revisiting as market demands change. As such, they pose interesting research challenges. The most important question, from our perspective, is how do we get industry to help identify current issues and future needs?

The examples of Roadmaps done in other Canadian industries offer some insight, but cannot necessarily be duplicated. For example, in the technology roadmap for the Canadian aerospace industry, "critical technology reports" for key technology areas were established and subsequently related to market demand research. The resulting technology matrix formed the backbone of the technology roadmap. However, the consultative process necessary to develop the critical technology reports was lengthy; this is a luxury not easily afforded in all cases.

The Mapping Model as a Consensus Building Tool

In the absence of numerous consultations with industry, we developed a technology mapping exercise that was both consistent with the research issues identified in this paper, as well as flexible, and capable of being administered in a survey format. The mapping model meets the demands of scenario planning as it establishes relationships between those elements that will determine what will happen. Table 1 outlines five key elements affecting transport demand and the technology market. In Figure 5, they become the five axes of a mapping template. Specific technologies are "mapped" according to their respective position on each axis.

Table 1 Technology Mapping Elements

Element	*Definition*
Market Drivers	*opportunities for profit*, or *competition* can pull forward technology; alternatively, regulatory change can be pushed by government as legal requirement to meet safety or environmental concerns.
Stage of Commercialisation	*level* of technology presently available
Price to Firm	investment cost to the firm of *adoption* of the presently available technology

Time to Implementation	the time frame for a user to acquire and implement a given technology
Economic Impact	the potential impact of adoption. A *breakthrough* has the greatest impact, potentially a quantum leap; an *incremental advance* to existing technology has a modest impact; *status quo* is just adopting the current industry practice

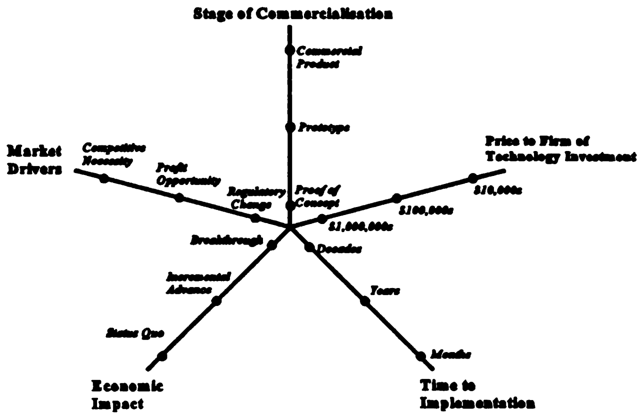

Figure 5 Technology Mapping Template

Preliminary results from the survey research, as well as experience using a similar model in the City of Winnipeg's *TransPlan 2010* process,[12] indicate that such a model is useful in establishing consensus - an important baseline for scenario analysis. In this sense, the mapping model also achieves many of the goals required for development of strategic paradigms. A strategic paradigm merely "defines a framework for conjecturing the future development" of industry by suggesting the appropriate directions in which technology can be developed.[13] The model does not pretend to be scientific. Rather it is intended to fill the conceptual gap that currently exists as a result of the shift away from traditional forecasting toward new ideas such as scenario analysis.

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ENDNOTES

1. The conceptual origins, and some of the terminology, of this paper lie in Moore (1996).

2. Examples of technology roadmapping, for the Canadian forestry and aerospace industries can be found on-line at Industry Canada's Web-site (http://strategis.ic.gc.ca).

3. Hackston *et al* (April 1997), p. 35.

4. These points are necessarily general. The particular drivers for specific commodity groups, and their respective modal and geographic implications, are treated in-depth in Hackston et al (1997).

5. The revolution in logistical thinking is not limited to freight, of course, and has driven changes in air and surface passenger transport.

6. Allen (1997)

7. i.e. what is required by the vehicle operator to keep the vehicle on the intended path and desired performance curve.

8. *Railway Age*, April 1997.

9. Personal Computers are a prescient example, experienced by almost everyone. Costs of upgrades are often not practical because the machine continues to function. However, the productivity of the workforce is hampered because the new software is not compatible.

10. There is a burgeoning literature on diffusion issues. Stoneman and Karshenas (1993).

11. Analysts differ on whether or not scenario analysis should augment, or replace, forecasting. See Wood (1997), Schnaars (1989) for the range of opinion.

12. Hicks, Tebinka and Prentice (1997).

13. See Metcalfe and Boden (1993)