Transportation Research Part C 17 (2009) 541–557

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

Intelligent freight-transportation systems: Assessment and the contribution of operations research

Teodor Gabriel Crainic [a,*], Michel Gendreau [b], Jean-Yves Potvin [b]

[a] Département Management et technologie, ESG and Interuniversity Research Centre on Enterprise Networks, Logistics, and Transportation (CIRRELT), Université du Québec à Montréal, C.P. 8888, succ. Centre-ville, Montréal, QC, Canada H3C 3P8
[b] Département Informatique et recherche opérationnelle and Interuniversity Research Centre on Enterprise Networks, Logistics, and Transportation (CIRRELT), Université de Montréal, C.P. 8888, succ. Centre-ville, Montréal, QC, Canada H3C 3P8

ARTICLE INFO

Article history:
Received 2 March 2007
Received in revised form 16 July 2008
Accepted 17 July 2008

Keywords:
Intelligent Transportation Systems
Freight transportation
CVO
AFMS
City logistics
e-Business

ABSTRACT

While it is certainly too early to make a definitive assessment of the effectiveness of *Intelligent Transportation Systems* (ITS), it is not to take stock of what has been achieved and to think about what could be achieved in the near future. In our opinion, ITS developments have been up to now largely hardware-driven and have led to the introduction of many sophisticated technologies in the transportation arena, while the development of the *software component* of ITS, models and decision-support systems in particular, is lagging behind. To reach the full potential of ITS, one must thus address the challenge of making the most *intelligent* usage possible of the hardware that is being deployed and the huge wealth of data it provides. We believe that transportation planning and management disciplines, *operations research* in particular, have a key role to play with respect to this challenge. The paper focuses on Freight ITS: Commercial Vehicle Operations and Advanced Fleet Management Systems, City Logistics, and electronic business. The paper reviews main issues, technological challenges, and achievements, and illustrates how the introduction of better operations research-based decision-support software could very significantly improve the ultimate performance of Freight ITS.

1. Introduction

The term *Intelligent Transportation Systems*, or ITS, is generally used to refer to tomorrow's technology, infrastructure, and services, as well as the planning, operation, and control methods to be used for the transportation of persons and freight. With ITS, however, tomorrow is already here.

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

* Corresponding author. Tel.: +1 514 343 7143; fax: +1 514 343 7121.
E-mail addresses: TeodorGabriel.Crainic@CIRRELT.ca (T.G. Crainic), Michel.Gendreau@cirrelt.ca (M. Gendreau), potvin@iro.umontreal.ca (J.-Y. Potvin).

0968-090X/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.trc.2008.07.002

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

While it is certainly too early to make a definitive assessment of the effectiveness of ITS, it is not to take stock of what has been achieved and, more importantly, to think about what could be achieved in the near future. In our opinion, ITS developments have been up to now largely hardware-driven, and have led to the introduction of many sophisticated technologies in the transportation arena. We are thus now, among other things, in the position to collect enormous amounts of data about the current state and the operations of transportation systems, and to transmit rapidly these data, in one form or the other, to transportation authorities, carriers, and travellers. Two critical questions remain though: are all of these data transformed into *useful information*? And, is this information *properly exploited*? The correct answer to both of these questions is clearly negative. The reason for this situation is that the development of the *software component* of ITS, models, decision-support systems, and so on, has been dramatically lagging behind that of its hardware component. In many cases, very detailed data are still processed and acted upon by the human operators with very few decision-support tools, if at all. In a sense, we are now faced with a challenge similar to the one that led to the initial development of ITS, that is, to make the best, the most *intelligent* usage possible of all that wonderful hardware that is being deployed. We believe that transportation planning and management disciplines, and in particular *operations research*, have a key role to play with respect to this challenge.

Challenges for the freight-transportation industry result from the major changes affecting supply chains and logistical processes in trade and commerce. The first factor is the strong impetus toward inventory reduction that led to the "Just-in-Time" procurement practices and, more recently, to just-in-time replenishments of goods in the retail industry. The globalization and liberalization of markets and the creation of free trade zones constitute the second major changing factor. The restructuring of manufacturing and distribution channels worldwide has accompanied the globalization of the economy. Production units are re-located, and the components required for the final assembly of complex industrial products are often brought in from many distant locations. Continuously increasing volumes of industrial, commercial, and consumer goods are imported into Europe and North America and transported over long distances from the so-called emerging-economy countries, e.g., China, India, and Brazil. All the while, trans-national centralized warehousing facilities and value-added distribution centers are changing the flow of goods almost everywhere.

The development of Internet-based electronic business is also strongly contributing to the transformation of the freight-transportation industry. The main external factors driving this transformation are the modifications to the logistic chains and practices of major industries and economic sectors, the proliferation of electronic spaces (websites) where shippers and carriers may meet and close deals, and the continuously increasing volume of individual consumer e-commerce activities. These changes have certainly resulted in higher demand for transportation. They have also increased the requirements for freight-transportation services in terms of enhanced customer value: reduce transportation and distribution costs, while responding to the customer needs in terms of delivery time and reliability. Moreover, events such as 9/11, the war on terrorism, and the war on drugs have created potential impediments to the flow of goods due to safety and security threats that can only be mitigated through the use of technology and increased efficiency.

Last but not the least, environmental and energy concerns are taking center stage. Indeed, the transportation sector is responsible of a significant amount of greenhouse gas emissions: 13% of all emissions of greenhouse gases and 23% of world CO_2 emissions from fossil fuel combustion (ITF, 2008). The last measure stands at 30% in countries of the Organisation for Economic Co-operation and Development (ITF, 2008) and was 27% in the United States in 2003 (EPA, 2006). It is estimated that the freight transportation contributes roughly a third of the CO_2 emissions of the world transport sector (ITF, 2008). This distribution is uneven, however, being worse in large cities, for example. Thus, a report by the Organisation for Economic Co-operation and Development (OECD, 2003) assigns 43% of sulphur and 61% of particulate matter emissions in London to freight transportation, while for nitrogen oxides emissions, the figures are 28% for London, 50% for Prague, and 77% for Tokyo. These contributions are growing and are expected to continue to grow with the increase in the freight-transportation activity and the corresponding consumption of fossil fuels. The impact on the freight transportation and logistics sector comes both from the initiatives to control, hopefully reduce, emissions and environmental impacts (e.g., vehicle emission legislation and environmental and congestion road pricing) and from the increases in the cost of energy.

These factors have put, and continue to put, tremendous pressure on the freight carriers and the managers of intermodal facilities to reduce and control costs, to plan and operate efficient, timely, and reliable services, and to react rapidly to new customer requests, emerging or shifting business opportunities, and changes in the economic and regulatory environment.

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