Fleet telematics
Real-time management and planning of commercial vehicle operations

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Abstract

Due to globalisation, liberalisation of markets, deregulation in the transport sector, and the increasing commitment to the just-in-time philosophy, competition between motor carriers and expectations on punctuality, reliability, flexibility, and transparency have increased significantly and will increase even more in the future. The rapid development of mobile communication and information technology allows the use of fleet telematics systems to cope with those challenges and to increase the efficiency of commercial vehicle operations. This work presents a telematics-enabled information system that alleviates a major obstacle for computer-based real-time decision support: the lack of timely and reliable information. A real-time decision support system is presented which achieves its strength from several specialised actors who collaboratively and concurrently modify problem data and solution, using different problem knowledge and solution techniques: dispatchers, a Messaging & Fleet Monitoring System, and a Dynamic Planning System. Several heuristic planning methods are presented which can be used to dynamically solve transportation problems incorporating a variety of real-life constraints that are not considered by the classical models found in the literature. Among those are the new regulations for drivers’ working hours in the European Union which entered into force in April 2007. With the improved availability of timely and reliable information provided by the Messaging & Fleet Monitoring System, and the real-time decision support provided by the Dynamic Planning System, this work gives an important contribution to increasing the efficiency of commercial vehicle operations.
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Chapter 1

Introduction

1.1 Motivation

Today, more goods are transported world wide than ever before. Globalisation and liberalisation of markets will lead to even more trade in future. From 1970 to 2000 the inland transportation within the European Union (excluding the new member states) has almost doubled\textsuperscript{1}. It appears that this considerable growth has been realised almost entirely by road transport which has almost tripled in the last 30 years. In other words, the proportion of road transport to total inland transport has grown from about one half in the year 1970 to about three quarters in the year 2000. According to a study by the European Commission\textsuperscript{2}, freight transport within the European Union (including the new member states) will increase by about 25% until 2010 and by almost 90% until 2030 compared to the values of 2000. It is assumed that this growth will also be realised almost entirely by road transport.

In some areas the volume of traffic today is already at a critical level and every day 7500 kilometres of European highways are blocked by traffic jams\textsuperscript{3}. The possibility of extending the road networks is very limited due to social, ecological, and economical reasons. As a result, road pricing systems are likely to be increasingly deployed to reduce the level of congestion and to finance infrastructural development.

\textsuperscript{1}See European Commission: Eurostat (2003)
\textsuperscript{3}See European Commission (2003a)
The deregulation in the European road transport market, in particular, the allowance of cab-
ottage operations, increases competition and motor carriers from emerging countries more
and more challenge motor carriers from developed countries by comparably lower wages.

Global competition forces manufacturing companies to improve the quality of their products
and to reduce their manufacturing costs. As a result, manufacturing companies increasingly
apply just-in-time practices in order to cut down inventory costs. Obviously, just-in-time prac-
tices necessitate punctual, reliable, and flexible transportation, as with reduced inventory
buffers any mismatch between supply and demand can result into significant disturbances
of manufacturing processes.

To face those challenges motor carriers have to increase the quality of service and reduce
costs. They have to increase punctuality, reliability, flexibility, and transparency of trans-
portation services, and, at the same time, have to reduce empty mileage and low vehicle utilisation. First motor carriers have pioneered using telematics in order to cope with these challenges in the end of the eighties1. Other motor carriers have followed and according to a
study by Frost & Sullivan2 there were 75,550 European commercial vehicles equipped with
telematics devices in the year 2001. This number is expected to rise to over 5.4 million in
2009. Rather than being a competitive advantage, the use of telematics to improve real-time
management and planning of commercial vehicle operations will more and more become a
necessity in order to survive in the highly competitive road transport market.

1.2 Purpose of this work

Typical commercial off-the-shelf fleet telematics systems can be used for information ex-
change between drivers and dispatchers, route guidance, and visualisation of vehicle po-
sitions on digital maps. They can give important information about the actual state of the
transportation system which is essential for real-time management and planning of com-
mercial vehicle operations. Many management information systems currently used by motor
carriers, however, do not provide methods for processing information obtained from fleet
telematics systems as, a couple of years ago, only very few commercial vehicles were
equipped with telematics devices. Therefore, fleet telematics systems often cannot be easily
integrated into the carrier’s information system and their deployment is of only limited benefit.

1 See Cohen (1995)  
2 See Frost & Sullivan (2002)
1.2 Purpose of this work

This work identifies and classifies potentials of fleet telematics and shows how commercial off-the-shelf fleet telematics systems can be integrated into a typical legacy information system without telematics functionality. A Messaging & Fleet Monitoring System is presented which supports the communication between drivers and dispatchers, monitors transportation processes, determines actual data, compares actual data with planned data, and revises planned data in order to consider the actual state of the transportation system. The telematics-enabled information system alleviates a major obstacle for computer-based real-time decision support: the lack of timely and reliable information. This work presents a Dynamic Planning System (DPS) for real-time decision support which exploits the improved knowledge about the actual state of the transportation system. The real-time decision support system achieves its strength from several specialised actors who collaboratively and concurrently modify problem data and solution, using different problem knowledge and solution techniques: dispatchers, Messaging & Fleet Monitoring System, and Dynamic Planning System.

The Dynamic Planning System uses algorithms to find high quality solutions to an analytical model. This model must map the real-life problem as precisely as possible as there is usually only little time to manually resolve infeasibilities resulting from an inappropriate model representation. Classical models for routing a fleet of commercial vehicles, however, oversimplify the problems that occur in practice, as pointed out by Bodin (1990) more than fifteen years ago. Although real-life problems are receiving increasing attention, this is still valid today, as stated by Kilby et al. (2000) “More effort has gone into methods for reducing the cost of solutions than supporting rich models. However, the problems faced in industry often require rich models ...”. This work introduces a unifying model, the General Vehicle Routing Problem (GVRP), which is a generalisation of various classical models. The GVRP is capable of considering a variety of real-life requirements such as load acceptance and employment of external carriers, time window restrictions, multiple pickup and/or delivery locations, multi-dimensional resource requirements, and a heterogeneous vehicle fleet. Although regulations regarding drivers’ working hours often have a big impact on total travel times, i.e. the time required for driving, breaks, and rest periods, they have only received very little attention in the vehicle routing literature. This work shows how regulations for drivers’ working hours in the European Union can be considered in vehicle routing and introduces the General Vehicle Routing Problem with Drivers’ Working Hours (GVRP-DWH).
If all relevant data are known, schedules can be generated statically. In most real-life applications, however, relevant data change dynamically while vehicles are en-route. Static vehicle routing problems have been intensively studied in the vehicle routing literature. Dynamic vehicle routing problems, however, only recently have found increasing attention. This work presents two insertion methods, a Reduced Variable Neighbourhood Search algorithm, and several variants of Large Neighbourhood Search algorithms for the dynamic GVRP and GVRP-DWH. These algorithms are characterised by very fast response times and can be used within the Dynamic Planning System. In order to evaluate the proposed algorithms benchmark problems are created that incorporate many characteristics found in dynamic real-life problems. Computational experiments are performed on these benchmark problems.

With the improved availability of timely and reliable information provided by automatically analysing messages sent by vehicles, and the real-time decision support based on algorithms for solving the dynamic GVRP and GVRP-DWH, this work gives an important contribution to increasing the efficiency of commercial vehicle operations.

This work should be of particular interest to transportation professionals who want to understand how fleet telematics can be used in order to increase the efficiency of commercial vehicle operations, to developers of logistics and optimisation software who want to incorporate real-time information into their software, to producers and vendors of fleet telematics systems who want a better understanding of the requirements of their customers, and to researchers and students interested in transport telematics and operations research.

1.3 Overview

This work is organised as follows. Chapters 2 and 3 give an introduction into the general topic of this work. Chapter 4 investigates how real-time information provided by fleet telematics systems can be incorporated into management information systems used by motor carriers. Chapters 5 and 6 introduce models and optimisation methods which can be used for real-life vehicle routing problems in which data may change dynamically.
1.3 Overview

Telematics

Telematics concerns the transmission of information over a telecommunication network combined with the computerised processing of this information. Chapter 2 gives an introduction into telematics and its main enabling technologies concerned with road freight transport. Wireless communication techniques which can be used for information exchange between dispatchers and drivers are surveyed. Another fundamental enabling technology for many telematics applications is the determination of a vehicle's position. Chapter 2 surveys the fundamental positioning systems used for in-vehicle positioning. Geographical Information Systems for Transportation are briefly introduced, as they are particularly required to determine shortest routes, and to map a vehicle’s position to the corresponding point in the road network. Eventually, chapter 2 surveys transport telematics applications which are of particular interest to motor carriers.

Commercial vehicle operations

Chapter 3 presents an overview over the development of road freight transport and its impact on commercial vehicle operations. The dramatic changes in the transport industry during the last decades are described and a brief look at the future development of road freight transport is given. The fundamentals of road freight transport are examined focusing on its main characteristics: transportation request, transportation resources, and the transportation services provided. Activities and management decisions of motor carriers can be categorised according to their impact on future operations. Chapter 3 discusses the different management levels: strategic, tactical, operational, and real-time management. Eventually, operational and real-time tasks are discussed in more detail before a case study is presented. In the following chapters the models and methods presented are also put in context to this case study.

Management information systems

Chapter 4 investigates management information systems used by motor carriers to perform their tasks at the operational and real-time management level. Many management information systems currently used do not have any telematics functionality as, a couple of years ago, only very few commercial vehicles were equipped with telematics devices. Chapter 4
briefly describes such a typical legacy information system, focusing on those functions affected by the communication possibilities between drivers and dispatchers. Functionalities provided by fleet telematics systems are described and potentials arising with the use of such systems are identified and classified. It is shown how commercial off-the-shelf fleet telematics systems can be integrated into a typical legacy information system without telematics functionality. A Messaging & Fleet Monitoring System is presented which supports the communication between drivers and dispatchers, monitors transportation processes, determines actual data, compares actual data with planned data, and revises planned data in order to consider the actual state of the transportation system. The lack of timely and reliable information used to be a major obstacle for computer-based real-time decision support. Chapter 4 presents a Dynamic Planning System which can be used to provide real-time decision support considering the improved knowledge about the actual state of the transportation system. A transaction control scheme is presented allowing dispatchers, Messaging & Fleet Monitoring System, and Dynamic Planning System to collaboratively and concurrently modify problem data and solution, using different problem knowledge and solution techniques. Directions for extending the telematics-enabled information system by additional functionalities provided by electronic freight markets are given. Chapter 4 concludes with a presentation of the implementation of the Messaging & Fleet Monitoring System and a prototype of the Dynamic Planning System.

Models for routing a fleet of commercial vehicles

Chapter 5 surveys classical models for routing a fleet of commercial vehicles and presents mathematical formulations of these models. Real-life vehicle routing problems encounter a variety of practical complexities which, to a certain extent, have been considered by the classical models. However, the classical models often oversimplify the problems that occur in practice. Chapter 5 introduces a general model, that can handle the requirements evolving from various characteristics found in real-life vehicle routing problems that are not considered by the classical models. This model, which will be termed the General Vehicle Routing Problem (GVRP), unifies the formulations of the Vehicle Routing Problem, the Pickup and Delivery Problem, and various variants and generalisations of these problems. Although regulations regarding drivers’ working hours often have a big impact on total travel times, i.e. the time required for driving, breaks, and rest periods, they have only received very little attention in the vehicle routing literature. Chapter 5 shows how regulations for drivers’ work-
ing hours in the European Union can be considered in vehicle routing and scheduling and introduces the General Vehicle Routing Problem with Drivers' Working Hours (GVRP-DWH). Chapter 5 concludes by showing how the problem the motor carrier of the case study has to face can be modelled as a GVRP-DWH.

**Dynamic vehicle routing**

The construction of schedules is a key issue for motor carriers and their success is highly dependent on the generation of good schedules. If all relevant data are known a priori, schedules can be generated statically. In most real-life applications, however, relevant data change while vehicles are en-route and schedules have to be updated dynamically. Chapter 6 investigates the main differences between dynamic and static planning. Algorithms developed for the classical models are surveyed, focusing on those that are suitable for rich vehicle routing problems in which data may change dynamically. Neighbourhood operators which allow to move from one feasible solution of the GVRP or GVRP-DWH to another feasible solution are introduced. Chapter 6 presents two insertion methods that can be used to quickly improve a solution considering new transportation requests arriving dynamically. Furthermore, a Reduced Variable Neighbourhood Search algorithm, which achieves its strength from changing the neighbourhood structure during the search, and several Large Neighbourhood Search algorithms, which iteratively remove an re-insert some of the transportation requests, are presented. The algorithms presented are characterised by very fast response times and can be used within the Dynamic Planning System. Computational experiments are performed to evaluate the algorithms presented.

**Conclusions**

Chapter 7 gives a summary of this work and a discussion of the scientific contributions. Eventually, some directions for future research are given.
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