Produktion und Logistik

Christoph Manuel Meyer

Vehicle Routing under Consideration of Driving and Working Hours

A Distributed Decision Making Perspective

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RESEARCH

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With a foreword by Prof. Dr.-Ing. Herbert Kopfer

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Foreword

In the European Union, statutory regulations restricting truck drivers' working and driving hours have been existing for several decades. Although these regulations have ever since been strictly prescribed by law and although their negligence in transportation planning and fulfillment was to be fined, they have only been of minor importance in the vehicle routing and scheduling literature so far. First and foremost, the techniques used for the documentation of the actual driving times and the methods for controlling the abidance by the law have changed the situation drastically. Since April 2007, the usage of digital tachographs has become mandatory in the European Union. At the same time, the new Regulation (EC) No 561/2006 on driving times of truck drivers has become effective. Due to the digital documentation, the surveillance of the driving times has become easier and can be performed efficiently by the control authorities. That is why the planning of breaks and rest periods has become a very important issue in vehicle routing and scheduling by now.

The PhD thesis of Christoph Manuel Meyer is one of the very early comprehensive monographs considering driving and working hours within vehicle routing and scheduling. Its main focus is on the distributed decision making perspective in the combined problem of vehicle routing and break scheduling. In his thesis, Christoph Manuel Meyer first presents a complete mathematical optimization model for the vehicle routing and scheduling problem with time windows which complies with the European legal rules on driving and working times. This model of the so called VRPTW-EU is used for computational experiments which generate some very interesting insights concerning the impact of including break scheduling in vehicle routing. Especially the relations among different goals of vehicle routing, such as travel distance minimization, minimization of the number of used vehicles and the minimization of travel and operating times are analyzed. Based on the introduced comprehensive and full model for the compound problem of combined vehicle and break scheduling and on useful separations of the entire model, the general framework of distributed decision making is applied to the decision problem under consideration. This leads to innovative distributions of optimization tasks between dispatchers and drivers which indeed are to a

high degree relevant for operational transportation planning processes in practice. Solving and analyzing both, the decision problem of the dispatcher and that of the drivers, and combining both problems requires the definition and application of adequate anticipation functions. Several experiments with different anticipation functions are conducted and reported in this thesis, showing the advantages and disadvantages of perfect explicit, approximate explicit and implicit anticipation. Apart from a mathematical model this thesis presents a restricted dynamic programming heuristic which solves the VRPTW-EU efficiently. By means of this heuristic, valuable experimental results could be derived which are useful for the application of the decentralized planning approach to vehicle routing.

This book presents and investigates the important extension of vehicle routing and scheduling by the aspects of break scheduling according to the regulations of the European Union. It proposes approaches for solving the expanded problem and analyzes the effects of including these regulations in transportation planning. Therefore, it is an essential and helpful reading for researchers and students of logistics, particularly for those with an engineering background. In addition, the contents of this book might be very interesting for executives and software engineers in the area of transportation planning.

Herbert Kopfer

Preface

This work is the result of my PhD project which I carried out at the Collaborative Research Centre 637 “Autonomous Cooperating Logistic Processes” at Bremen University from November 2006 until December 2010. Many people have contributed to the success of this project to whom I would like to express my gratitude. First of all I would like to thank my supervisor Prof. Herbert Kopfer. He offered me the chance to come to Bremen and to work on this very interesting and challenging topic. With his deep knowledge in the fields of logistics and Operations Research he supported me throughout my PhD project. Apart from providing me with such a pleasant working atmosphere at the Chair of Logistics, he introduced me to the scientific community at various conferences all over the world, which I enjoyed very much.

I would also like to thank Prof. Hans-Dietrich Haasis for writing such a positive review for my PhD thesis. Moreover, despite the snow chaos, Prof. Herbert Kotzab made his way to Bremen to take part in my PhD defense, which I appreciate very much.

My thanks also go to my colleagues from the Chair of Logistics, especially to PD Dr. Jörn Schönberger, Xin Wang and Sebastian Sterzik for their participation in my PhD defense. Apart from that, Xin Wang took the time and effort of proof reading my PhD thesis for which I feel much obliged.

In 2009 I spent three months as a guest researcher at the Department of Industrial Engineering at Pusan National University, South Korea. I would like to express my gratitude to Prof. Kap Hwan Kim for allowing me to join his team and to take part in his research seminar. And I would like to thank the German Research Foundation (DFG) for supporting this stay.

During my PhD project I had a very fruitful and pleasant cooperation with researchers from the University of Twente where I was allowed to spend a couple of weeks as a visiting scholar. I would like to thank Prof. Henk Zijm and Dr. Marco Schutten for their kind invitation to Enschede. And I would like to express my heartfelt gratitude to my friend Dr. Leendert Kok for our very successful cooperation, for the nice time we had together in Enschede and Bremen, and for

showing me how to “live on the edge” from an Operations Research perspective.

I would also like to express my gratitude to the Gabler Verlag team, namely Prof. Hans-Otto Günther, Mrs. Stefanie Brich and Mrs. Nicole Schweitzer, for their good and reliable cooperation concerning the publication of my thesis.

I would never have succeeded in finishing my PhD thesis without the support from my family and friends. Therefore, I would especially like to thank my parents Jutta and Bernd Meyer for their support during my studies and during my time as a PhD student. The certainty that I could always rely on them gave me the confidence to start this PhD project and helped me overcome many obstacles in its course. Furthermore, I would like to thank my friend Ellen Kremer for her backup during a particularly difficult time of my PhD project. Finally, my great thanks go to my friend Juliane Riese for her hint concerning the benefits of bibliography management systems, for always being there for me, and for the great time we had together when I could free myself from my PhD project.

Christoph Manuel Meyer

Contents

List of Figures

List of Tables

Abbreviations

AETR European Agreement concerning the Work of Crews of Vehicles Engaged in International Road Transport

ArbZG Arbeitszeitgesetz

DDM distributed decision making

DMU decision making unit

DOT Department of Transportation

DP dynamic programming

EC European Community

EEC European Economic Community

FTL full truckload

LTL less-than-truckload

PDP Pickup and Delivery Problem

PDPTW Pickup and Delivery Problem with Time Windows

PVRP Periodic Vehicle Routing Problem

PVRPTW Periodic Vehicle Routing Problem with Time Windows

TSP Traveling Salesman Problem

TSPTW Traveling Salesman Problem with Time Windows

TSPTW-EU Traveling Salesman Problem with Time Windows and European Union Social Legislation

TW time window

VRP Vehicle Routing Problem

VRPTW Vehicle Routing Problem with Time Windows

VRPTW-EU Vehicle Routing Problem with Time Windows and European Union Social Legislation

1 Introduction

Driver fatigue is a major issue in road transportation. In Germany, 48,324 accidents were registered in 2008 in which trucks were involved (Federal Statistical Office, 2010). The Federal Road Research Institute (Bundesanstalt für Straßenwesen) estimates that 19 percent of the serious truck accidents in Germany are caused by driver fatigue (Federal Road Research Institute, 2006). According to a representative study by the International Road Transport Union which was commissioned by the European Community (EC), overfatigue and falling asleep is the cause in approximately 18.6 percent of single truck accidents, i.e. accidents in which no other party is involved (International Road Transport Union, 2006). The European Commission even estimates driver fatigue to be a significant factor in approximately 20 percent of all heavy commercial vehicle crashes (European Commission, 2010). Recent studies on road safety show that after four hours of continuous driving, the accident risk is doubled, and after eight hours of continuous driving it is even ten times higher (Goudswaard et al., 2006).

To counter this situation, the European Union enacted stricter laws on driving and working hours of persons engaged in road transportation. Regulation (EC) No 561/2006, which came into effect in April 2007, restricts driving hours of truck drivers. It is supposed "to improve working conditions and road safety" (Regulation, 2006, Article 1). Drivers' working hours are restricted by Directive 2002/15/EC which was enacted in March 2002 (see Directive, 2002). Together, these laws are often referred to as *European social legislation*. This denotation will also be used in the following.

The working time directive had to be implemented into the national laws of the member countries of the European Union to become effective. In Germany, its rules were included in §21(a) of the Law on Working Hours (Arbeitszeitgesetz (ArbZG)) which became effective in August 2006. In order to provide that drivers have enough time for recuperation, the European social legislation restricts the maximum admissible driving and working times and sets minimum requirements for breaks and rest periods. Whether the enacting of these laws really helped to improve road safety has not yet been proved. However, it is remarkable that in Germany the total number of road accidents in which trucks were involved

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dropped by 5.4 percent from 51,075 in 2007 to 48,324 in 2008. In the years prior to that, only slight decreases could be noticed. The number of truck accidents amounted to 51,745 in 2005 and 51,334 in 2006 (Federal Statistical Office, 2010).

1.1 Problem Description

The European social legislation imposes restrictions on driving and working hours of drivers engaged in road transportation, which are valid on different but interconnected time horizons, reaching from single driving periods up to periods of several weeks. These rules define a complex set of restrictions which have to be respected by all freight forwarding companies operating within the member states of the European Union, Switzerland and the countries party to the Agreement on the European Economic Area. Freight forwarding companies are forced to organize their drivers' working times such that they can obey the legal rules (Regulation, 2006, Article 10). Through the introduction of digital tachographs, enforced by Regulation (EC) No 561/2006 in combination with Regulation No 1360/2002 (see Regulation, 2002), infringements of the legal rules can easily be detected by control authorities.

Within freight forwarding companies, dispatchers or planners are responsible for the design of vehicle routes.[1] They have to assign transportation requests to vehicles and their drivers such that the transportation requests are fulfilled as specified by the customers. These specifications usually comprise pickup and delivery locations, characteristics of the load to be carried, time windows during which the goods have to be loaded and delivered, and possibly other specific requirements such as temperature control. The design of vehicle routes meeting all the above requirements is in itself a complex task, which is usually referred to as the *vehicle routing and scheduling problem*.

Apart from these requirements set by the customers, dispatchers have to create vehicle routes such that the legal rules on driving and working hours can be respected by the drivers. For drivers' infringements of the European social legislation, also their employers can be held responsible.

The integration of driving hours regulations in the design of vehicle routes presents new challenges for dispatchers at freight forwarding companies. Apart from the already highly complex problem of vehicle routing and scheduling, breaks and rest periods for each driver have to be planned. The vehicle routes have to

[1] In the following the terms "dispatcher" and "planner" are used synonymously.