Chapter 1

Introduction

This chapter starts with a motivation of the investigated topic "Dynamic Fleet Management for International Truck Transportation with occasional transportation tasks", considering practical relevance and previous attention in the existing literature (Section 1.1). In Section 1.2 the goal of the study and the main research questions are outlined. In Section 1.3 a review of developments towards the application of Dynamic Fleet Management Systems is given, followed by an analysis of the freight forwarding market in Germany and Europe (Section 1.4). Finally, this work's course of action is explained (Section 1.5).

1.1 Motivation

Tour planning has been a popular field in Operations Research since the 1960s (Dantzig and Ramser, 1959). A large number of researchers have dealt with all kinds of static problems, developing a huge variety of procedures. In recent years, the *center of attention has* also *moved to the field of dynamic tour planning problems*, where new information evolves concurrently to the plan execution and has to be handled efficiently by the dynamic planning approach (see Chapter 2 for a detailed definition of the term *dynamic*).

Many authors have developed dynamic procedures, basically extensions to already existing static ideas. In the majority of cases, the dynamic publications were focused on *local area* problems with the goal of minimizing traveled distance (see Chapter 3 for a Literature Review). There are only a few works available so far that have dealt with dynamic *wide area* planning problems.

This finding may be due the *predominance of line transportation* in wide area environments: A recurring medium-term plan – effective for several weeks or months – is generated and constitutes each vehicle's circulation between the nodes of a *fixed transportation network* (e.g., operation of a driving route from location A to B every Monday morning). New requests are fed into the driving routes of the existing line operation schedule, which, for example, induces advantages in consolidation of less-than-truckload requests. Short-term dynamic planning is not necessarily required.

However, it can be observed that some internationally operating freight forwarding companies – Willi Betz International, LKW Walter, Hindelang, etc. – have also successfully specialized in another type of *wide area* freight transportation: in *occasional transporta-*

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tion, independent of predefined networks – also referred to as "ad hoc" or "tramp transportation" (Falk, 1995). Since there is no line schedule on a fixed network, there is the need for dynamic replanning to react in the short term on newly occurring requests and other changing information. Primary objectives are the minimization of empty traveled distance, the minimization of delay and high vehicle utilization.

Today, those companies do not apply any dynamic algorithms for their tour planning. Planning tasks, like order-to-vehicle assignment, vehicle routing and scheduling are performed completely manually by human dispatchers. This raises the question of whether there has been sufficient consideration of the planning problem *dynamic International*[1] *Truck Transportation with occasional transportation tasks* in the existing literature.

There is a small group of available publications that cover the specified planning problem: e.g. Powell (1996), Powell et al. (2002) and Yang et al. (2004). However, one drawback is that most of the specific *European real-life requirements for long-haul transportation* have been neglected in these publications. Even in the available static literature, requirements for International Truck Transportation are only *partially* considered, in some of the latest publications (e.g. Kok et al., 2009). A *complete* consideration of such requirements, however, is needed for a freight forwarding company's[2] planning system, since compliance with requirements (like EC social regulations) is statutory.

In addition to the incomplete real-life requirements, the available (static) wide area publications have only been tested with self-generated artificial test data. The applied test data sets all possess an unrealistically small quantity of vehicles and orders, and contain an inadequate duration of maximum six days. This is not sufficient to test a *wide area* planning procedure, since some restrictions take effect only over a horizon of several weeks. Due to their static character, the available publications do not consider any implementation aspects, which, however, are a crucial component in getting a dynamic planning system up and running at a freight forwarding company.

As far as we know, there is no work available that includes all the subsequent aspects that are important in practice: (i) development of a Dynamic Fleet Management System for International Truck Transportation focusing on occasional transportation tasks, (ii) comprehensive consideration of all important real-life restrictions for Europe-wide Truck Transportation, e.g. EC social regulations, working time restrictions, traffic bans, etc., (iii) test of the procedure with a sufficiently large real-life data set (in terms of duration, number of orders and number of vehicles), and (iv) benchmark with actual planning performed at a freight forwarding company.

Due to the obvious negligence of this field of dynamic tour planning, the untreated aspects are selected for investigation in this work.

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[1] We use the term *international* with a focus on Europe; synonymously with *wide area* or *long-haul*.

[2] The term *freight forwarding company* (German: Spedition) is primarily directed at the *agency function* of organizing shipments for individuals or other companies. A *freight forwarding company* is often not active as a *carrier* and outsources the actual execution to *road haulage companies* (German: Transportunternehmer/Frachtführer) (Bundesverband Güterkraftverkehr Logistik und Entsorgung (BGL) e.V., 2010). In this work, however, we use the term *freight forwarding company* for both types of company.

1.2 Goal of the Study and Problem Outline

The *goal of the study* is:

> *To design a Dynamic Fleet Management System for International Truck Transportation focusing on occasional transportation tasks that is capable of improving the planning process at a freight forwarding company in terms of empty traveled distance and service quality, hereby taking into account all important European real-life requirements (EC social regulations, working time and traffic bans).*

In the following, a number of *research questions* are posed. These questions outline the research problem in more detail and shall guide us in reaching the goal of the study.

What are the specific characteristics of dynamic planning problems?

Dynamic planning problems differ in many aspects from static ones. Before a new dynamic planning procedure is developed, the specific characteristics of dynamic planning problems have to be elaborated. They can be helpful for adjusting a new planning procedure in order to meet the specific needs of a dynamic planning problem.

Where do dynamic planning situations occur in real-life?

Before a new dynamic planning procedure is developed, it is also interesting to evaluate where dynamic planning situations actually occur in real-life and to what theoretical planning problems they can be connected. This analysis legitimates the treatment of the dynamic planning problem that was chosen in this work. It also helps to assess the real-life value of other dynamic publications from the literature.

What is the state of the art in the literature on Dynamic Fleet Management?

Before designing a solution method for the selected real-life planning problem, we need to familiarize ourselves with the state of the art in the literature on this topic. Since the literature on dynamic wide area applications is scarce, we discuss the literature on dynamic routing problems in general. The investigation of algorithm orientated papers gives us an idea, with what procedures best performance could be achieved.

What dynamic solution approaches are suitable for a Dynamic Fleet Management System?

We develop a choice of two planning approaches with two completely different planning ideas. First stage, the approaches are not designed for the final planning problem with all its real-life restrictions, but instead, for a simplified local area problem. The available test instances for this local area problem are used to perform extensive tests and to evaluate the strengths and weaknesses of both procedures. One procedure is finally chosen for adaptation to the real-life planning problem.

What general requirements come along with International Truck Transportation?

In order to achieve an operable Fleet Management System, we need to elaborate the real-life restrictions that have to be actually considered for Europe-wide Truck Transportation. EC social regulations, working time restrictions and traffic bans are analyzed in detail. The main restrictions are chosen for inclusion in the real-life planning procedure.

What specific requirements are necessary to cover the planning situation at the cooperating freight forwarding company?

Incorporating the general planning requirements does not necessarily result in actual real-life applicability. The specific planning situation at a freight forwarding company, which comes along with additional restrictions, has to be considered as well. To this end, we perform a detailed analysis of the planning process and of the planning data of our co-operating freight forwarding company and adjust our planning procedure to the specific situation.

What simulation speed should be used to evaluate the real-life planning procedure's performance?

In the selection process of an appropriate procedure and at the final calculations with the real-life test data set, we face the question of how to run simulations: with high or slow speeds. A high simulation speed produces results faster and therefore allows for more simulation runs. This can be an advantage, since it allows for a higher number of different parameter variations to be tested. A slow simulation speed (e.g., real time simulation), however, allows for more improvement calculations to be executed during each simulation run. Therefore, this type of simulation is supposed to produce a better overall solution quality (at least, if the planning procedure is capable of using the available time).

How much potential savings can be generated with the application of a computer-based dynamic planning system for International Freight Transportation? Is it reasonable to implement such a Decision Support System?

We compare the results that can be achieved with the newly developed planning procedure (for a five-week real-life data set) with the manual planning performed at our cooperating freight forwarding company (benchmark). From this, we derive the potential savings in empty traveled distance and delay that can be generated with the application of our computer-based planning system. This is followed by a discussion of the pros and cons of an actual implementation of such a Decision Support System.

1.3 Developments towards Dynamic Tour Planning

There are several developments that promote the popularity of Dynamic Tour Planning. Significant *advances in information and communication technologies* contribute the necessary technical requirements. *Increased competition* and *rising environmental awareness* call for efficient planning and the economical use of resources.

In addition, there is also a *consolidation* and *growth* effect (more vehicles and more orders per company) that makes it more difficult to achieve good planning results by manual planning, thus triggering the implementation of a computer-based Decision Support System for Dynamic Fleet Management.

Subsequently, these aspects are explained in more detail.

- **Advances in information and communication technologies:** Today, the *real time determination of a vehicle's position via GPS* is state of the art. *Mobile communication* can be used to exchange information between planning center and driver.

  Figure 1.1 shows an exemplary information flow in a GPS-based dynamic Fleet Management System (cp. Larsen, 2000; Goel, 2007). The vehicle in motion receives at least three positioning signals from GPS satellites and calculates its current position. This position is transferred via GSM cellular phone network to the planning center. The planning center knows all the vehicles' status, all the open orders etc. and produces a preferably good vehicle dispatching (order to vehicle assignment, vehicle routing, vehicle scheduling). Afterwards, planning decisions and updates are transferred via GSM back to the vehicle. Communication between planning center and driver may be text message based as well as by phone.

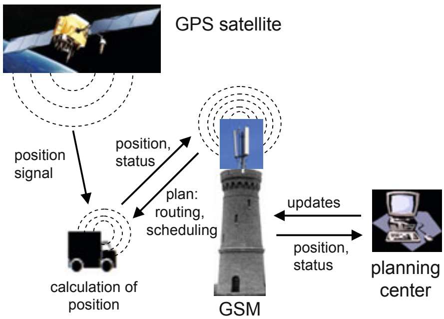

Figure 1.1: Information flow in a dynamic routing system (Larsen, 2000)

  In addition, the use of the latest *digital road maps* and the *inclusion of actual traffic information* to calculate shortest paths between Pickup and Delivery locations has become standard. Route planners (e.g. PTV map&guide, Tele Atlas) are employed at the planning center as well as directly at the vehicles.

  A further aspect concerning information technology is the *improved capacity of computing systems*. At the planning center today, a single personal computer is able to quickly handle large amounts of data, e.g. processing the complete planning of a truck fleet operating Europe-wide.

- **Increased competition:** The introduction of a *single European transportation market* has reduced market barriers and allows freight forwarders from each European country to offer international transportation services over the entire European territory.

  Cabotage (the execution of a transportation service within a country by a foreign freight forwarder), however, is still restricted: according to regulation EC 1072 of 21.10.2009 (European Union, 2009) cabotage is only allowed subsequent to an incoming international transport. In such a case, a vehicle may only execute a maximum of three cabotage transports, with the last Delivery having to be finished within seven days of completion of the incoming international transport (Freight forwarders from Bulgaria and Romania are excluded from this partial authorization of cabotage until 31.12.2011).

Since 01.01.1994, *prices* for freight transportation are no longer subject to regulation and can be *freely negotiated with regard to supply and demand* (Staub et al., 2004). Internet market places (freight exchanges) allow a shipper to find the cheapest freight forwarder, while freight forwarders may offer free transportation capacity to the highest bidder. In addition to reduced geographical market barriers, such freight exchanges provide order mediation as well as market transparency concerning supply, demand and prices. This is of special interest for small and medium-sized freight forwarding companies that do not have their own distribution channels.

Furthermore, a *harmonization and simplification of the general conditions in the European countries* has been initiated. Since 2006, driver based social regulations (see Section 5.1 for further details) are the same over the whole of Europe. However, there are still major differences in taxation (e.g., company and fuel taxation) as well as labor costs. While average yearly labor costs per employee in the transportation sector in 2005 was at a level of € 45,000 in Belgium and € 32,700 in Germany, an employee in Bulgaria only earned € 3,900 (Eurostat, 2009).

Profit margins in the freight forwarding sector are *quite low*. According to Commerzbank Research (2010), the average EBIT (Earnings Before Interest and Taxes) in the German freight forwarding sector was 4.2% (reference year: 2006), with a spread between -3.0% and 13.6%. An effective real time planning system may help to gain competitive advantages and to ensure a company's survival.

- **Environmental awareness:** In the recent years, *environmental awareness* has attracted a great deal of attention in politics and the public. Freight forwarders are in specific focus, since 26% of the EU-27's total energy consumption can be attributed to road transport (reference year: 2006; Eurostat, 2009). Efficient planning, e.g. by minimizing empty traveled distance, therefore, is not only a necessity for direct cost reduction, but also a socially desired objective.

- **Growth:** In a work by Powell (1996), it is reported that a higher number of available vehicles spread over the area of execution produces a smaller percentage of empty traveled distance (economies of density). This is an intuitive finding. The drawback, however, is the *increasing planning complexity*. A human dispatcher who is simultaneously managing a large number of vehicles will be barely able to "optimally" react to a large amount of very frequently changing data (realistic dimension for a big freight forwarder: 1000 vehicles in motion, and 2000 open transportion orders). In the case of several human dispatchers, who manage distinctive subproblems, the generation of a "globally optimal solution" is becoming even more unlikely.

  A computer based dynamic Fleet Management System, however, can create "good solutions" in quick response to a large, varying information base, simply because there is enough computation power to consider the planning problem as a whole and to evaluate many more possible planning options in the short period of available reaction time.

1.4 Market Analysis

A look at the *European, and specifically the German, freight forwarding market* shows a strong growth in truck transportation volumes over the recents years. In the following, some statistics are presented which confirm this statement and which also try to explain this development. In addition, trends in prices and in the number of freight forwarding companies are considered.

The freight forwarding sector is an important economic factor, accounting for 7% of the European Union's value added and employing 8.7 million people (reference year: 2005). In the years from 1995 until 2008, the European transportation market grew by 33.6%, from 3,060 billion tkm to 4,090 billion tkm. Figure 1.2 shows the transportation performance of the modes road, sea, rail, inland waterway, pipeline, and air. Over the whole considered horizon, it can be observed that road transportation accounts for the highest transport performance with a successively increasing gap to the other modes. While in 1995 only 42.1 %tkm of the total goods transportation were executed by truck, in 2008 the share of truck transportation increased to 45.9 %tkm (Eurostat, 2009).

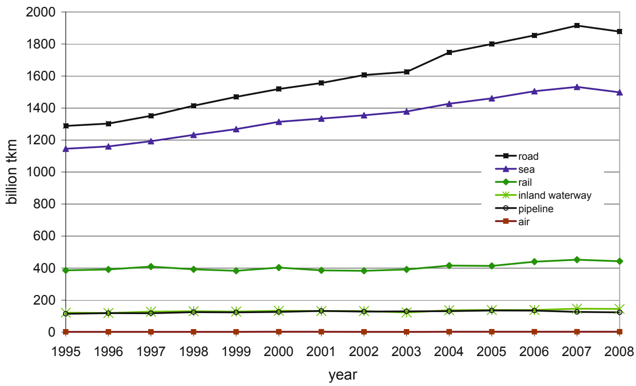

Figure 1.2: Modal split EU27: 1995 - 2008 in billion tkm

From many shippers' perspectives freight transportation by truck seems to remain the preferred choice. In a survey, Pfohl and Schäfer (1998) asked 134 companies that order logistical services how they would rate the performance of different traffic carriers (truck, airplane, rail, waterway sea, waterway inland, and intermodal transport) for seven key indicators on a scale from 1 (worst qualification) to 5 (best qualification). The results are presented in Figure 1.3.

In terms of *transportation time*, *network connections*, *flexibility*, and *reliability*, truck transportation is rated best. Interestingly, the *transportation costs* per truck also outperform the other traffic carriers. Only in *adherence to schedule* and *tracking and tracing* the airplane is rated slightly better.

In the following, the specific development of the German freight forwarding sector is analyzed (Statistisches Bundesamt Deutschland, 2010; Commerzbank Research, 2010):

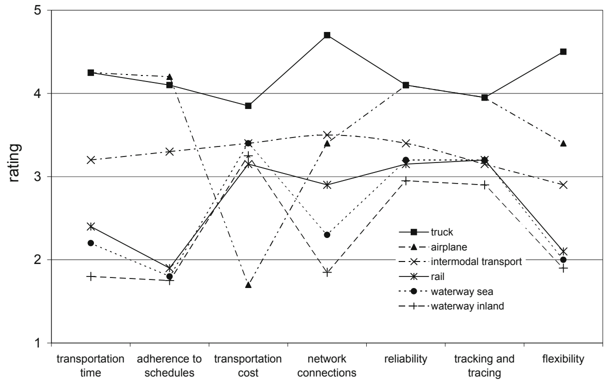

Figure 1.3: Assessment of different transportation modes from a shipper's perspective

In Figure 1.4 the sales volume is processed for the years 2001 until 2009. A substantial growth in sales volume (+68%) can be observed between 2001 and 2008, reaching a maximum sales volume of € 74.74 billion in 2008. Afterwards, the world financial crisis caused a reduction in sales volume to € 62.63 billion in 2009.

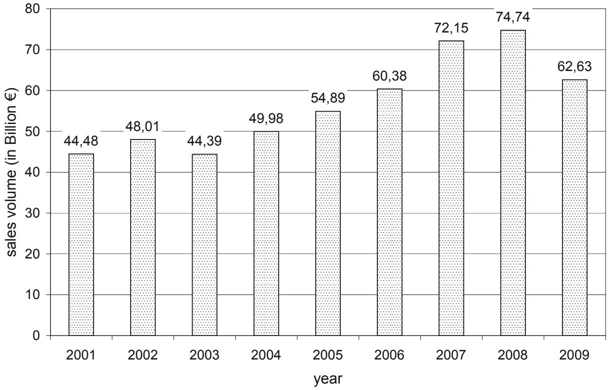

Figure 1.4: Sales volumes in the freight forwarding sector (Germany): 2001 - 2009

The previously mentioned growth of the European transportation performance (in tkm) of +33.6% over a 13-year horizon, and the development of the sales volume in the German freight forwarding sector (in €) of +68% over a 8-year horizon cannot be directly compared. Nevertheless, these numbers suggest that an overproportionately high share of the European growth was generated by German freight forwarders.

A look at the prices that had to be paid by the shippers is given in Figure 1.5. Especially in 2005 and 2006, freight forwarders were able to achieve higher freight rates (+7.2% and +8.1%, respectively). In 2009, however, the reduced transportation volume led to overcapacities, resulting in decreasing market prices (-1.7%).

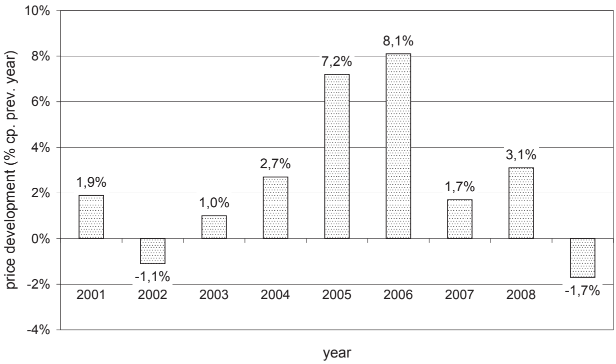

Figure 1.5: Development of prices for freight forwarding services (Germany): 2001 - 2009

The last statistic deals with the development of the total number of freight forwarding companies in Germany (Figure 1.6). Similar to the increases in sales volume, the number of freight forwarders increased by 41% between 2001 and 2008. In 2009, however, a substantial decrease in the number of freight forwarding companies is reported.[3]

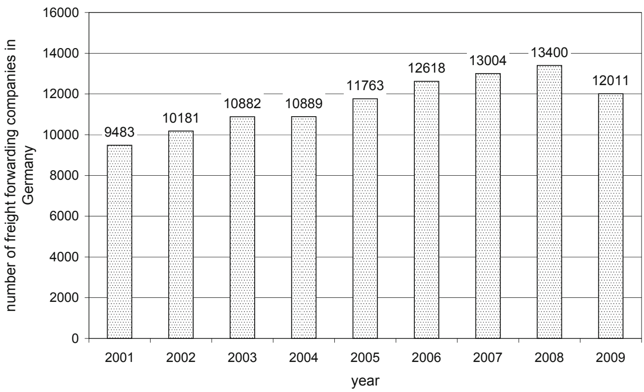

Figure 1.6: Number of freight forwarding companies (Germany): 2001 - 2009

1.5 Course of Action

This section describes the main contents of the following chapters. The sequence of investigated topics roughly complies with the sequence of research questions that have been proposed in Section 1.2.

[3] It should be mentioned that this statistic also includes very small freight forwarding companies. Here, the minimum requirement to be counted as a freight forwarding company was a sales volume of at least 17,500 Euro

Chapter 2 includes a general **characterization of dynamic vehicle routing problems** and proposes a configuration framework for such kind of problems (Section 2.1). Furthermore, the most relevant dynamic real-life applications are elaborated and connected with the associated theoretical problem definitions (Section 2.2). Finally, two relevant dynamic problem specifications (a local and a wide area one) are selected and characterized for further consideration (Section 2.3).

Chapter 3 includes a detailed **literature review** of publications on *Dynamic Fleet Management*. At the beginning, some general statistics on the surveyed literature are given (Section 3.1), followed by some exemplary publications showing the variety of dynamic applications in real-life (Section 3.2). Afterwards, algorithm orientated papers are classified into three groups, depending on the knowledge of the future (Section 3.3). The first two groups do not have any knowledge of the future and therefore only perform *myopic* planning. In contrast to the first group, the second group, however, tries to anticipate the future. Stochastic information about the future is available only in the third group of publications, where the algorithms make explicit use of such information.
The remaining sections review the most popular dynamic test instances in the literature (Section 3.4) and present the results of some papers that do not primarily focus on the algorithmic performance but on the acceptance of dynamic planning applications in real-life (Section 3.5).

In **Chapter 4**, **two dynamic planning procedures are developed and evaluated:** Multiple Neighborhood Search (Section 4.1) and an Assignment based procedure (Section 4.2). For reasons of simplicity, the procedures' basic versions are directed to the local area capacitated MLPDPTW (covering the dynamic real-life application of Dial-A-Ride Services) and not to the final real-life planning application.
Both procedures' specific characteristics are compared in Section 4.3, elaborating the main differences. Afterwards, some test data sets - self-generated as well as taken from the literature - are introduced (Section 4.4). These data sets are used for a comparison of the procedures' performance and also to gain some general insights in dynamic problems (Section 4.5). Finally, one procedure is chosen for adaptation to the real-life scenario (Section 4.6).

In **Chapter 5** the selected basic solution approach is adapted to perform actual **real-life application at an Internationally Operating Freight Forwarding Company**.
Firstly, the requirements that have to be considered for long-haul transportation in Europe are elaborated (Section 5.1). Afterwards, the actual planning process at the leading European freight forwarding company is drafted (Section 5.2). Section 5.3 describes the adaptation of the Multiple Neighborhood Search procedure to the real-life planning situation. In Section 5.4 the preprocessing of a five-week real-life test data set and the derivation of benchmark objective function values are explained. Finally, the computational results that are achieved with the adapted Multiple Neighborhood Search for this real-life data set are reported (Section 5.5).

In **Chapter 6** methodology, achievements and main findings of the study are summarized (Section 6.1). Afterwards, some recommendations for further research in the field of *Dynamic Fleet Management* are proposed (Section 6.2).