Car Rental Logistics Problem: A Review of Literature

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Abstract—**This paper will introduce a special kind of logistics management problem which exists in the car rental industry. Revenue management conception has been used for reference in the car rental industry to develop booking, pricing and inventory strategies. In order to get a high degree of customer satisfaction and optimize vehicle fleet utilization, logistics managers in the car rental business approximately adopt three decision-making steps: namely, pool segmentation, strategic fleet planning and tactical fleet planning. Optimizing resource deployment and reducing the logistics cost are the targets of logistics management in enterprise. We will review the existing literature on the car rental logistics problem and identify some gaps in current research. This sort of research is prospective and useful for future development of the car rental industry.**

Keywords- car rental logistics; optimize resource deployment; revenue management;demand forecast; fleet assignment problem

I. INTRODUCTION

Car rental industry can date back to the 20th century when two important people (i.e., Walter L. Jacobs and John D. Hertz) auspicated this business in American. After the development of nearly one century, the revenue of car rental business per year has been up to one hundred billion US dollars, and it has become a significant role for the world economic development. In the United States, about one third new cars are sold by the channel of rental every year; similarly, two millions which account for fifteen percent of new cars are sold by the same way in Japan.

The focus of our research is to consider the problem faced by a car rental company needing to fulfill the optimization of logistics process for a heterogeneous vehicle fleet. The main objective of this study is to review the literatures and identify gaps in former research concerning the car rental logistics management. We consider the logistics processes in the car rental industry. Car rental companies must deal with the car imbalance issues and deploy various types of vehicles among each rental locations by means of trucks or other freight manners. As car rental companies provide substitutional products, price and service quality are critical success factors. This underlines the importance of optimizing car rental logistics in terms of the utilization of the fleet of cars while maintaining a high degree of customer satisfaction, and makes it possible to provide a kind of caring service [1].

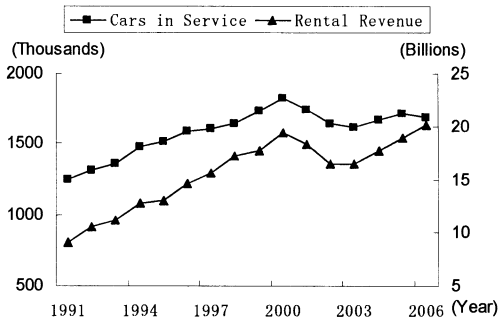
This article is hereafter organized as follows: In the following section, we will introduce the development of car rental industry. Section 3, the car rental network and logistics process will be described. Section 4 is devoted to the development of revenue management and its application in the car rental industry. In section 5, we will review the literature of fleet assignment problem including demand forecasting and the deployment of cars among pools or locations. Lastly, section 6 will draw conclusions and analyze the future research orientations of car rental logistics management.

II. THE DEVELOPMENT OF CAR RENTAL INDUSTRY

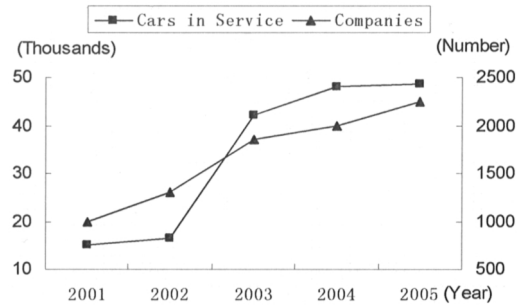
From the point of view of market development, especially take US and China for example, the cars in service and rental revenue have come into being an approximately stable scale in US (see Fig.1) due to the increasing competition and never-ending rate wars according to the Auto Rental News [2]. By the end of 2006, the number of car rental companies has reached more than six thousand all over the world, in which Hertz and Avis as well as Euro car are representatives.

In China, a developing country, the investigation results (see Fig.2) show that the car rental market has been actively exploiting since 2001, and the operating abilities and scale of car rental companies are upgrading ceaselessly [3].

In effect, car rental business is running to the mode of a large-scale operation. By adopting two common patterns, car rental companies achieve their operation expansion. One is M&A (i.e., Merger and Acquisition) that need to input material and human resource; the other is concession that only needs to enhance management and cooperation.



Firgure 1. Statistics of car rental industry in US



Firgure 2. Statistics of car rental industry in China

III. PROBLEM DESCRIPTION

A. Car Rental Network

Most of famous car rental companies have several thousand locations all over the world, which are used to provide rental service for their customers. Therefore, there is an obvious logistics management problem in the service operation process. For a large-scale car rental company, the rental locations are scattered around the world, while its daily operation is based on a country even a special region (that is so-called pool).

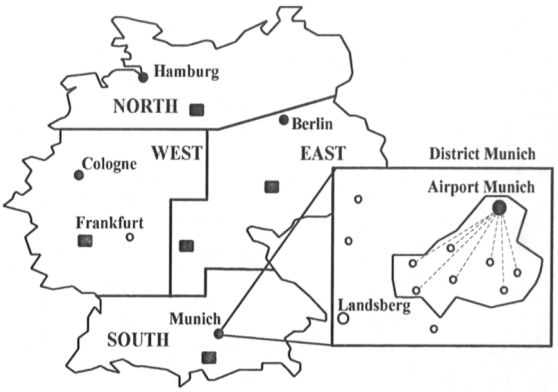
A network with hierarchical structure contains some locations of different scales and functions. Customers put forward the rental demand by internet, phone and other communication ways, or book the cars from locations in person. The rental locations provide proper cars according to the reservations to meet the demand of customers and reclaim the mature cars. A possible structure of a car rental network in Germany with four regions is shown in Fig.3, which includes all stations in and around the city Munich [1].

B. Logistics Processes

New cars produced from the manufactures are delivered to certain car rental company by trains or trucks, and then transferred to locations. Logistics operations mainly pay attention to the processes of cars' transferring, which can assign resources among rental locations. To obtain a high yield, car rental companies attach great important to proper planning and execution of these vehicle deployment decisions [4]. The aim of logistics management is to optimize car deployment by means of fleeting, transfers between stations, and defleeting, focusing on short-term logistics decisions for a planning horizon from a few days up to one or two weeks [1].

IV. REVENUE MANAGEMENT

The naissance of revenue management or yield management, a novel operation management technology, was in the late 1970s, when American airlines faced more complexly competitive circumstances than before. Revenue management is the process of maximizing revenue through management of perishable inventory (seats on an airplane, rooms in hotel, or cars in a rental fleet) and price. Its aim is to help firm sell the right inventory unit to the right type of customer at the right time and place for the right price [5].



Firgure 3. Possible structure of a car rental network

However, the goal is not only to maximize yield, but also to allow for finding the optimal tradeoff between average price paid and capacity utilization, and to be meaningful in all applicable industries [6]. Revenue management became a fad, a "magic cure" [7]. It is a powerful new spin to the old game of supply and demand management [8]. It can help decision makers adjust the pricing and inventory policies by the chances in demand to obtain more revenue.

Revenue management was successfully used in airline industry, and quickly extended to other sectors. A sample of related literatures in other sectors is listed in a table [9]. Especially, revenue management has been used for reference in the car rental industry by Hertz in 1989 even under the more complex conditions. Car rental systems must deal with a more migratory inventory, a more decentralized management of inventory, and a larger set of customer options than do airline or hotel revenue management systems (see Tab. I). Rental Car Yield Management at Hertz is different from the existing airline yield management technology. It has three groups of primary users, they are regional managers, local city managers and headquarters in functional departments [10]. One of the distinct differences of car rental revenue management from its application to airlines is the degree to which price changes [11]. But revenue management can effectively meet the needs of customers by arranging the cars lying idle and raise the price while there are strong demands. By applying analytic models and methodologies to a planning horizon, revenue management achieves revenue gains and saves National Car Rental [12].

TABLE I. VARYING COMPLEXITIES AMONG THREE INDUSTRIES

Comparison Items	Airlines	Hotels	Rental Cars
Inventory	Seat	Room	Car
Number of Unit Types	1-3	1-10+	5-20+
Total Units By Location	Fixed	Fixed	Variable
Mobility of Inventory	Small	None	Considerable
Rates Per Unit	Many (3-7+)	Few (2-3+)	Many (4-20+)
Duration of Use	Fixed	Variable	Variable
Corporate Discounts	No	Yes	Yes
Inventory Managed	Central	Central	Central/Regional/Local

V. KEY ISSUES

In practice, to get a high degree of customer satisfaction and optimize vehicle fleet utilization, logistics managers in the car rental business approximately adopt three decision-making steps: namely, pool segmentation, strategic fleet planning and tactical fleet planning. First, divide all rental locations into some pools by certain principles, so that each pool can share a fleet of vehicles for a period time. Second, decide types and size of cars for each pool. Finally, according to the reservations and demand forecasting information, and combine with the booking, pricing and inventory polices, carry out short-term deployment of the fleet in every pool.

A. Fleet Assignment Problem

Transportation process is a hotspot of optimization approach application, such as VRP (vehicle routing problem) and VSP (vehicle scheduling problem). Research of FAP (fleet assignment problem) based on revenue management originally launched in airline industry as well, as shown in Tab. II. FAP deals with assigning aircraft types, each having a different capacity, to the scheduled flights, based on equipment capabilities and availabilities, operational costs, and potential revenues [13]. The results of FAP can affect subsequent planning, marketing, pricing, and operation processes within the airline.

FAP in the car rental industry is to maximize revenue by assign inventory (i.e., the cars distributing among stations located in different places) to rental locations. For a large-scale car rental company which has a rental network in a certain region, the holding costs will increase along with the cars lying idle, and deficient inventory will degrade the service level. Service is defined in terms of waits for a requested car or car type that is not available [10], and service level is the ratio of reservations be met under the premise of no upgrading product provided [14]. Upgrade policy is a common method in the rental industry when there is no available corresponding commodity.

The decision of FAP is the key of logistics process optimization, the linchpin of adjusting supply and demand. It can affect the company revenue greatly, so car rental companies attach importance to FAP all along. In the actual operations, FAP is accomplished via a sequential hierarchical structure composed of three phases: (1) pool segmentation, (2) SFP (strategic fleet planning), and (3) TFP (tactical fleet planning) [15]. In general, most of the important field operations are organized on a pool basis [16]. The rental locations are divided into relatively independent pools based on location distances and demand changing character as well as other factors (including number of locations in a pool, transportation fees, and so on). A pool is an operation unit, which have some affiliated locations and share a fleet of cars. The second and third phases decide the cars deployment among pools and locations for a certain period based on the rental demand forecasting.

B. Demand Forecast

The Demand levels are forecasted at two primary levels of aggregation: length-of-rent and on-rent. Length-of-rent determine the time of car returned, and on-rent refers to the number of cars in use on a specific date [12]. The demand forecasting for all levels of aggregation is based on a combination of long-term and short-term forecasting corresponding to the SFP and TFP. In addition, no-show and walk-in rates are high in the car rental industry, so we need to explore the changes of demand. Deciding the inventory of a pool or a location at any time is fundamental to successful car rental operations. Long-term forecasting pays attention to the development of market prospects, while short-term forecasting concerns about the integration effect of rental rate and the stochastic factors. The check-in and demand for a given city might look like the curves in Fig.4, where D_i represents consecutive days of the week. For most major commercial airports, D_1 would be Sunday or Monday while for many downtown and suburban locations D_1 would be Wednesday or Thursday. The shade region represents the "critical period" for a city when demand potential comes close to or exceeds capacity [16].

The station, the period within a week, the lead time, and the car group are identified as four main factors that affect a linear regression functions, which is assumed to map reservations to a forecast of rental requests. This result in the following general regression function (the subscripts/indices represent factor combinations):

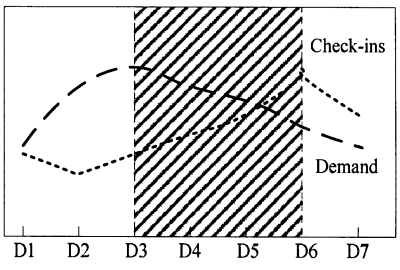
$$\#check-outs_{[station,\ period,\ leadtime,\ group]} = a_{[station,\ period,\ leadtime,\ group]} + b_{[station,\ period,\ leadtime,\ group]} \times \#reservations_{[station,\ currentperiod+leadtime,\ group]} \quad (1)$$

The parameters a and b of these regression functions are estimated on the basis of data [1].

C. Strategic Fleet Planning and Tactical Fleet Planning

SFP and TFP problem are the cores of FAP. A car fleeting decision impacts the rental company revenues highly. Assigning a smaller amount fleet than needs in a pool or a rental location will result in supply insufficiency, which may lower service level and lost some longstanding customers. On the contrary, assigning a larger amount fleet will result in overstock, which may waste resources and lost the chance to get more revenue.

The SFP starts along with the accomplishment of pool segmentation. In this stage, the size of cars for each pool will be determined, which will hold the line in the planning horizon. The TFP treads on the heels of SFP. It is carried out for each pool on a daily basis. Its function is to determine the optimal fleet levels for all locations within a pool and the required vehicle transfers among locations.



Firgure 4. A possible demand pattern

TABLE II. FAP IN AIRLINES INDUSTRY

Journals	Authors	Year	Research contents
Interfaces	Abara, J.	1989	The research proposes an integer linear programming model, permitting assignment of two or more fleets to a flight schedule simultaneously [18].
	Subramanian, R. Scheff Jr, R.P. Quillinan, J.D. et al.	1994	Solve FAP by a large-scale mixed-integer linear program so as to minimize a combination of operating and passenger "spill" costs, subject to a variety of operational constrains [19].
Operations Research	Berge, M.E. Hopperstad, C.A.	1993	Develop an operating concept, namely, Demand Driven Dispatch (D^3), which addresses the FAP [20].
Operations Research Letters	Z. Gu E. L. Johnson G. L. Nemhauser et al.	1994	Mainly study the difficulty of solving the basic fleet assignment problem and the behavior of the solution as a function of the number of fleets [21].
Mathematical Programming	C. A. Hane C. Barnhart E. L. Johnson et al.	1995	Present a large multi-commodity flow problem with side constraints defined on a time-expanded network to solve FAP, and carry out a case study [22].
Management Science	D. Guy D. Jacques D. Yvan et al.	1997	Propose two equivalent models for DARSP (the daily aircraft routing and scheduling problem). Computational results shown that the Dantzig-Wolfe decomposition or the column generation technique can be used to solve real problems [23].
European Journal of Operational Research	I. Ioachim J. Desrosiers F. Soumis et al.	1999	Based on Dantzig-Wolfe decomposition or column generation to solve FAP, and introduce a new type of constrains, related to schedule synchronization [24].
Transportation Science	R. Brian B. Cynthia K. Tim et al.	2000	The research assumes that flight demand is constant and independent of the flight departure times and fleet assignment. FAP with time windows problem is modeled as a simple variant to the basic problem [25].
	B. Cynthia S. K. Timothy L. Manoj	2002	Find out several shortcomings of basic fleet assignment models, and propose a new formulation and solution approach capturing network effects [26].
	L. Manoj B. Cynthia	2004	Present two new integrated models and solutions algorithms for airline schedule design and fleet assignment [27].
	B. C. Smith E. L. Johnson	2006	Develop a station decomposition approach that takes advantage of the hub-and-spoke network typical of major airlines [28].
Transportation Research Part B: Methodological	N. Belanger G. Desaulniers F. Soumis et al.	2006	Address FAP for a weekly flight schedule, and prove the possibility of generating assignments with a relatively high level of homogeneity without sacrificing too much expected profitability [29].
Informs Journal on Computing	R. K. Ahuja J. Goodstein A. Mukherjee et al.	2007	Develop the combined through-fleet-assignment model, which integrates two airline scheduling models, the fleet-assignment model and the through-assignment model, and propose a swap-based neighborhood search algorithm [30].

The pool segmentation problem can be solved by means of column generation solution algorithm. The SFP and TFP problem is formulated as a network structure with side constraints [17]. The objective function of TFP stochastic optimization problem is defined as the summing the expected revenues of all locations within the pool and subtracting the costs of transshipping vehicles among locations. Then the problem is decomposed into two disjoint subproblems, namely, the fleet deployment subproblem (FDP) and the transportation subproblem (TP).

By relaxing some of the assumptions of the model FD, three new TFP models to address some important features that are of interest to practitioners are proposed [4]. Fink and Reiners (2006) modeled the TFP problem with the objective of maximizing profit by balancing supply and demand from the perspective of short-term logistics management. The model is based on a rolling planning horizon of one week, and describes this problem on a time-space network [1].

Truck rental industry is similar to the car rental industry. Determining the optimal size of a fleet consists of strategic, tactical and operational decisions. First, define markets and customer service levels. Second, determine asset purchases and sales. Finally, confirm asset allocation, assignment, routing, and scheduling. To carry out the final decisions, including customer demand allocation and empty truck repositioning along with asset purchase and sale decisions over space and time, Peiling et al. (2005) develop a two-phase approach for the rental fleet-sizing problem based on Benders decomposition and Lagrangian relaxation [31].

VI. CONCLUTIONS

The purpose of this article is to provide a new starting point for future research on the logistics management in the car rental business by reviewing relevant existing academic literatures. For the whole industry, optimizing the logistics process is an important measure to obtain revenue, but, as showed above, literatures are mainly absorbed in describing some application systems in the car rental industry while academic article is obviously insufficient. Our knowledge in this field is extremely superficial and must be increased.

The optimal efficiency of logistics management can be enhanced by virtue of more powerful decision-making models, and more integrated notions of FAP and revenue management are necessary as well. We list the future research orientations about this problem as follows:

A. Car Rental Demand Forecast

Forecast is the basis for decision making, so more accurate models must be built. The car rental industry is different from airline or hotel industry. The difficulty of demand forecast lies in how to consider customers' behavior characters, such as the high rate of no-show, returning cars remotely, and the uncertainty of length-on-rent.

B. Fleet Assignment Problem

Actually, in the third stage of FAP, the current literatures have not taken into account the case of "downwind cars", which is to deploy the cars by customers. Although the rental price is cut-price, car rental companies sometimes provide some homologous services for customers in order to accomplish the logistics operation when the transportation volume is small.

C. Evaluation of Logistics Management

The evaluation result of logistics management is a gist to judge the logistics operation scenario. Given that a solution is calculated by the FAP model, a reasonable result should be provided in order to present an evaluation in advance or reference for amelioration afterwards.

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