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A study on the vehicle size and transfer policy for car rental problems

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ABSTRACT

This study addresses the problems of fleet size and vehicle transfer for car-rental companies with multiple branches. The problem is formulated as a constrained mixed-integer programming model within an environment of dynamic demand. We develop a hybrid heuristic approach to solve this problem, using quantitative results to demonstrate the robustness and effectiveness of the proposed approach. We apply the proposed model to the analysis of a case involving a car-rental company in Taiwan. Sensitivity analyses are also conducted to investigate the effects of various system parameters on the computational results.

1. Introduction

Car rental companies are considered to have moderate potential for growth. According to a report by Before It's News, the industry is expected to reach a value of US$67.6 billion by 2017, with a compound annual growth rate (CAGR) of 3.5% over the next five years (see Lucintel, 2012). To operate their businesses in the long term, car-rental companies must determine the total fleet size for each rental car group. In their daily operations, these companies strive to achieve maximum efficiency from their vehicle fleets. In practice, vehicles are often expected to return to the branches at which they were rented. To offer better service to their customers, however, many companies allow users to return vehicles to different locations for an additional fee.

Car rental companies can increase their competitiveness by offering this service. Nevertheless, because return locations have a direct impact on vehicle stocks, the practice can eventually lead to significant imbalances between supply and demand for most branches (Kochel et al., 2003). Vehicle-transfer planning helps to overcome this problem (Carroll and Grimes, 1995; Li and Tao, 2010). Issues to be considered in such planning include fleet deployment, which determines fleet levels for all branches) and transportation operations, which anticipate the required vehicle transfers among local branches (Pachon et al., 2003; Fink and Reiners, 2006; Ernst et al., 2010; Guerriero and Olivito, 2013).

The literature contains a wide range of discussions concerning problems of fleet size and transfer. The fleet-size problem relates to capacity planning, which involves determining the capacity needed to meet future demands for its products or service. Literature review on capacity planning models can be found in Luss (1982) and Van Mieghem (2003). The vehicle-transfer problem relates to fleet management, which involves such issues as vehicle transshipment and vehicle financing.

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Notation

M	number of branches
T	number of planning days
$f_{ti}(\theta_{ti})$	probability of θ_{ti} requests arriving at Branch-i in period t
c_{ij}	the variable transportation fee per kilometer when dispatching cars from Branch-i to branch-j
k_{ij}	the fixed transportation fee when dispatching cars from Branch-i to Branch-j
μ_{ti}	mean requests at Branch-i in period t
g_{ij}	penalty cost for one unit of unmet demand from Branch-i to Branch-j
h_i	daily operating cost per car for Branch-i
p_{tij}	the proportion of requests for rental type (i,j) in period t to all requests at Branch-i in period t
r_{ij}	revenue per car for rental type (i,j). $r_{ij} = r^b_{ij} + e_{ij}$

Decision variables

x_{ti}	deployment level at Branch-i on the morning of day t
y_{tij}	number of empty cars dispatched from Branch-i to Branch-j in the evening of day t
z_{tij}	1 if empty cars are dispatched from Branch-i to Branch-j in the evening of day t and 0 otherwise
W	fleet size

Many authors have explored transshipment problems for the airline and rail industries (see Sherali and Maguire, 2000; Kwon et al., 1998; Spieckermann and Vob, 1995). Similar to the car-rental industry, these industries must also re-balance their capacities, albeit for different reasons. In the airline and rail industries, these decisions are driven by such factors as flight schedules and train routes. In the car-rental industry, they are driven by vehicle imbalance (Li and Tao, 2010).

The problem of vehicle-transfer planning has also been discussed in the context of carsharing systems, which constitute a mode of transportation between car rental and taxis (Kek et al., 2009). They are based on the concept of cooperative car schemes that allow people access to cars without having to own them (Seik, 2000). With respect to trip configuration, Correia and Antunes (2012) note that carsharing systems can be classified as either round-trip systems or one-way systems. In the round-trip system, a vehicle is picked up from and returned to the same station. In the one-way system, users are allowed to return vehicles to other stations. The latter system is clearly more convenient for users. It may nevertheless lead to vehicle-stock imbalance. Like car-rental companies, carsharing operators overcome this problem by addressing the issues of stocking and relocating vehicles. Kek et al. (2009) proposed a three-phase optimization-trend-simulation decision support system for carsharing operators to determine manpower and operating parameters for the vehicle relocation problem. Correia and Antunes (2012) proposed a mixed-integer model to deal with the depot location problem to maximize the profits of a one-way carsharing organization. In their paper, the vehicle stock imbalance issues were addressed under three trip selection schemes.

The problems of vehicle-transfer planning addressed in the literature are typically formulated as linear programming models (Beaujon and Turnquist, 1991; Sherali and Tuncbilek, 1997; Powell and Carvalho, 1998; Sayarshada and Ghoseiri, 2009), integer/dynamic programming models (Kochel et al., 2003; Fink and Reiners, 2006; Topaloglu and Powell, 2006; Ernst et al., 2007, 2010, 2011; Westphal and Krumke, 2008; Song and Carter, 2008; Guerriero and Olivito, 2013), or queuing models (Savin et al., 2005; George and Xia, 2011; Papier and Thonemann, 2011).

In many cases, linear programming models aim to develop efficient algorithms for solving large-scale problems in a short computing time. Such models are essentially deterministic, however, treating uncertainty through expectations. Time–space models (e.g., dynamic and queuing models) are able to consider the interdependence between periods and between locations. Due to their computational complexity, however, these models are usually incapable of producing exact solutions for large-scale systems. Most of these models therefore focus on developing effective approximation techniques for the value function (see Li and Tao, 2010 and George and Xia, 2011).

Most large-scale problems are formulated as time–space linear programming models under the assumption that the arrival patterns of customers are constant over time. In many cases, however, the arrival patterns of customers may change over time, and they do not necessarily follow a certain pattern over the entire planning period. For example, demand at metropolitan locations reaches a peak on weekends, due to leisure or family-related activities. In contrast, demand at highway locations reaches a peak on mid-week days, due to business travel (Pachon et al., 2006). These models are therefore not necessarily suitable for handling situations in which demand fluctuates dramatically over time. Accordingly, many researchers have addressed this problem by considering the environment of dynamic demand.

Most previous works examining time-dependent demand have focused on either fleet sizing or vehicle transfer, and few have considered the combination of both problems (Kochel et al., 2003). Song and Earl (2008) developed an integrated model for fleet-sizing and empty vehicle repositioning problems for a two-depot system under the condition that requests can