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A MIP model to optimize real time maintenance and relocation operations in one-way carsharing systems

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Abstract

The daily management of a one way carsharing system is focused on relocation and maintenance operations. On one hand, the freedom of allowing users to return vehicles wherever they want leads to vehicle imbalance problems and on the other hand, a system where the same vehicle is used by different persons, has the need for daily maintenance operations. Demand is a key element that influences both relocation and maintenance needs, and the system has to be prepared to adapt and react to it in an optimized way. This paper describes the optimization model integrated in a tool developed to manage relocation and maintenance operations of a one-way carsharing system in real time. The optimization model developed is a mixed integer linear programing model, instant-based and designed to work using a rolling horizon. The division of the operation time into planning horizons allow the updating of the system status data, which provides a closer connection to the system reality. The model considers that crew elements use mainly the vehicles of the system to move inside the operating area, and orders are remotely transmitted through a wireless communication platform to mobile devices. Three types of activities are attributed to crew elements: waiting, maintaining the vehicles and moving. The mathematical model discriminates each crew element and is able to decide the best schedule for each one. It has flexibility to select between crew trip joining or crew trip splitting, in order to reduce movement cost or relocate a higher number of vehicles. Simulation tests were performed to assess the computer processing time for different problem sizes.

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Keywords: carsharing, maintenance, relocation, optimization

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1. Introduction

Carsharing is a form of collaborative consumption consisting in the timesharing of vehicles, allowing its use for short periods of time, less than a day. Organizations promoting carsharing own a fleet of vehicles making it available for people to share (Millard-Ball et al., 2005). To gain access to the system, individuals must meet the membership requirements of the carsharing organization, which can include an annual fee. After the membership process is fulfilled, users can have immediate access to the available vehicles whenever they want, without needing to fill a rental agreement each time a car is used. Users pay a usage fee for time and distance travelled, which already embeds fuel and insurance.

In terms of carsharing operational characteristics, two main categories can be distinguished: location of vehicles and allowed movements.

Concerning the location of vehicles, the system can be station based (discrete) or free floating (continuous). In station based services, vehicles are located at pre-defined places. Those can be stations, parking lots or reserved street parking areas. Free floating services, are characterized by having its vehicles parked at any place, with legal public access, inside a pre-defined zone. Free floating system vehicles have on-board GPS equipment to ease management and allow users to locate them by using a smartphone (Shaheen et al., 2015).

Allowed movements can be subdivided in round trip and one way. In roundtrip services users need to return the vehicle to the same place where it has been picked up. In one way carsharing services, movements to another destination different than the origin are allowed, which means that there is no imposition to return the car to any particular place (Barth and Shaheen, 2002).

The simplest operational set up is round trip and station based. This is the choice of systems with a small number of vehicles and stations, since it is easy to manage and doesn't require many staff hours, nonetheless it is not adapted to users' needs. By increasing one step on the level of operational complexity, we have one way and station based systems. One way movements give more flexibility to users, being a critical factor to attract new clients to the system (Efthymiou et al., 2013). Additionally, it lets a higher utilization of vehicles as they do not need to be idle during the rental period as it happens when clients are forced to a roundtrip. The downside is that it can lead to having a surplus of vehicles in stations with high demand as destination, and a lack of vehicles in stations with high demand as origin, unbalancing the demand and supply quotient (Barth et al., 2004). The most complex operational set up is one way and free floating. This allows individuals to use a vehicle of the system as if it was their own vehicle. However, it doesn't mean complete freedom, since vehicles need to be delivered inside an operating area (Shaheen et al., 2015).

The imbalance problems created by one way movements need to be solved by the operator to minimize the rejected demand and increase vehicle availability levels. This can be done by intervening on the demand side or on the supply side (Jorge and Correia, 2013). The amount of vehicle usage in a system with scale to be one way, implies the need for daily maintenance operations, such as vehicle cleaning and refueling. Therefore the use of staff to perform both maintenance and relocation operations should be regarded.

This paper describes a model developed to simultaneously optimize maintenance and relocation operations in an one way carsharing system that can be used for station based as well as free floating system settings. The model is instant-based and designed to work in a rolling horizon planning approach. It uses carsharing system vehicles to assist staff movements, as much as possible.

2. Literature review

The imbalance problem that arises by allowing one-way movements has been addressed in different ways. According to Jorge and Correia (2013), there are three main approaches to assist the daily system management operations: operator-based relocations, user-based relocations, and trip selection. In operator-based relocations, staff is used to periodically drive vehicles from a station with an excess of vehicles to a station with a shortage of vehicles. In user-based relocations, balancing movements are performed by clients reacting to incentive mechanisms, usually based on price. Trip selection consists in controlling the demand by allowing only the trips that are favorable to the balance of vehicle stocks.