Transportation Research Part C 72 (2016) 130–142

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

A Spatial Hazard-Based analysis for modelling vehicle selection in station-based carsharing systems

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ARTICLE INFO

Article history:
Received 15 March 2016
Received in revised form 19 September 2016
Accepted 19 September 2016

Keywords:
Carsharing
Hazard based modelling
Choice set formation
Vehicle selection

ABSTRACT

Carsharing, as an alternative to private vehicle ownership, has spread worldwide in recent years due to its potential of reducing congestion, improving auto utilization rate and limiting the environmental impact of emissions release. To determine the most efficient allocation of resources within a carsharing program, it is critical to understand what factors affect the users' behavior when selecting vehicles. This study attempts to investigate the importance of users' attributes and fleet characteristics on choice set formation behavior in selecting vehicles using a Spatial Hazard Based Model (SHBM). In the SHBM model, "distance to a vehicle" is considered as the prospective decision criteria that carsharing users follow when evaluating the set of alternative vehicles. This variable is analogous to the duration in a conventional hazard-based model. In addition, user socio-demographic attributes, vehicle characteristics, land use type of the trip origin, etc., collected from the Australian carsharing company GoGet are utilized to parameterize the shape/scale/location parameter of the hazard function. A number of forms of parametric SHBMs are tested to determine the best fit to the data. The accelerated failure time model with a Log-logistic distribution was found to provide the best fit. The estimation results of the coefficients of the parameters can provide a starting point for carsharing organizations to optimize their pod locations and types of cars available at different pods to maximize usage.

1. Introduction

In recent times, transportation planning has focused on the concept of sustainability. The goal of a majority of transport planning practices is ensuring a livable community for the current generation whilst considering the impact on future generations. A number of transportation authorities have recognized that private car ownership has significant costs associated to individuals and transport authorities in relation to purchase and maintenance costs as well as the provision of infrastructure (Duncan, 2011). In addition, increased private vehicle use has resulted in traffic congestion. Some of the repercussions due to traffic congestion include excessive delay, increased fuel consumption, greater road infrastructure costs and higher levels of emissions reducing air quality, which has resulted in significant economic and social costs (Wijayaratna, 2013; Banister, 2005; Catalano et al., 2008). In order to mitigate congestion, planners have advocated the development and use of public transit, carpooling, walking and cycling. Carsharing schemes, a form of short-term car rental, have become a

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http://dx.doi.org/10.1016/j.trc.2016.09.008
0968-090X/

complement to the previously mentioned sustainable transport approaches. Since its inception in the 1980s, carsharing schemes have become a crucial element of sustainable transport systems within the modern urban cityscape.

Studies have shown that carsharing scheme has the advantage to reduce the number of vehicles required to meet the total travel demand (Barth and Todd, 1999). Further, it has the potential to reduce congestion, provide more equitable access to private transport and limit the environmental impact of emissions release (Duncan, 2011). These advantages have resulted in an increasing development of carsharing programs as a mode of transport in planning for a sustainable transportation system. Thus, it is critical to understand what factors affect the demand for carsharing to further their usage. Demand is dependent on trip attributes such as: trip purpose, duration of the trip, time of day and week and also the vehicle selected out of the available choices. Jorge and Correia (2013) presented a comprehensive literature review regarding demand modelling approaches for carsharing programs. The paper highlighted that demand estimation is difficult due to the interdependency of vehicle availability and the number of trips. Furthermore, there has been limited research into understanding and characterizing the supply within modelling frameworks. In order to evaluate carsharing programs effectively, the demand for and the supply provided must be accurately determined. With respect to the supply of vehicles, carsharing programs can be categorized into free-floating and station-based systems based on facility configuration. Free-floating systems allow users to pick up and drop off a car freely in a defined zone without any fixed positioning. Station-based systems provide users with multiple predefined "pick up and drop off" vehicle pods (Firnkorn and Müller, 2011), which can be further classified into round-trip and one-way trip carsharing systems based on trip configuration. Station-based systems are less flexible for the consumer but more widely adopted by carshare operators. This study focuses on station-based carsharing systems and aims to advance the existing literature by investigating users' vehicle selection behavior which is constrained by the supply of vehicles within station-based carsharing facilities.

Users' vehicle selection is a significant factor in determining the most efficient allocation of resources within a carsharing program. Vehicle selection is the decision process undertaken by an individual to select a specific vehicle given a choice of vehicles within a carshare fleet. By understanding vehicle selection, programs can optimize the vehicle utilization within the fleet. Thus, this study attempts to answer two questions: "How far is an acceptable walking distance when users make decision on using carshare vehicles?" and "What factors influence users' selection of vehicles?" Since the choice set of carshare vehicles is very large, users will follow two steps to make the decision. First users screen the alternative and come up with a small and manageable choice set and second they make their selection from options considered in the choice set. The paper attempts to present a method for the first step while the second step in which advanced discrete choice models will be used in undergo as the next step of this paper. Users' cognitive capacity for screening and filtering alternatives from a choice set based on a critical or influential factors is an essential component of first step of vehicle selection behavior (Rashidi and Mohammadian, 2012). Accessibility to carsharing facilities dictates the utilization of carsharing facilities. Thus, the main factor affecting the choice set of vehicles is considered to be the "distance to the carsharing vehicle within a specific carsharing facility". A Spatial Hazard Based Model (SHBM) has been formulated using data provided by GoGet, an Australian carsharing company. The SHBM is applied instead of a discrete choice model since it is more consistent with users' vehicle selection process than discrete choice models. The modelling was achieved by considering "distance to the carsharing vehicle" as a random variable analogous to the duration in conventional HBMs. A number of parametric forms of HBM were tested to determine the best fit to the data set. The two major contributions of this study are: (1) introducing an analytical modelling structure for modelling demand for carsharing with a focus on vehicle selection and (2) application of a choice set formation technique that has been previously applied to a housing search problem (Rashidi and Mohammadian, 2012).

The remainder of the paper has been structured in the following manner. Section 2 provides a detailed literature review discussing the recent studies within carsharing demand modelling and the application of HBMs within the field. The collection and preparation of the data sets used to formulate the model are discussed in Section 3. The modelling framework and analysis methodology of the spatial hazard based model is then explained within Section 4. This is followed by Section 5 which presents the results and analysis of the modelling. Finally, the implications of the results and future research surrounding this topic are highlighted within Section 6.

2. Literature review

The history and development of carsharing programs provide a source of motivation for this investigation. In terms of transport planning, carsharing program is a travel demand optimization strategy. Carsharing offers the user the choice to forego ownership of a vehicle as he or she will still have access to a private vehicle when it is absolutely necessary for specific trip purposes, as a result this has the potential to reduce the number of vehicles travelling within the overall network. Martin et al. (2010) studied the impact of carsharing on household vehicle holdings in North America and presented that the average number of vehicles per household dropped from 0.47 to 0.24 for households which utilize carsharing. Furthermore, the analysis suggests that carsharing has removed 90,000–130,000 vehicles from the road at an aggregate level. The latest three-year study on one-way carsharing services of five major cities in North America also demonstrated the mileage reduced by carsharing has exceeded the mileage created by it, resulting in a decrease in annual vehicle mileage by 10–29 million miles per city investigated (Martin and Shaheen, 2016). A vast amount of literature has highlighted the advantages of carsharing programs (Shaheen et al., 1998; Stillwater et al., 2009; Duncan, 2011; Jorge and Correia, 2013; Shaheen and Cohen, 2013). For