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A simple reservation and allocation model of shared parking lots

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ABSTRACT

With increasing auto demands, efficient parking management is by no means less important than road traffic congestion control. This is due to shortages of parking spaces within the limited land areas of the city centers in many metropolises. The parking problem becomes an integrated part of traffic planning and management. On the other hand, it is a fact that many private parking spots are available during daytime in nearby residential compound because those residents drive their cars out to work. These temporarily vacant parking lots can be efficiently utilized to meet the parking demand of other drivers who are working at nearby locations or drivers who come for shopping or other activities. This paper proposes a framework and a simple model for embracing shared use of residential parking spaces between residents and public users. The proposed shared use is a winning strategy because it maximizes the use of private resources to benefit the community as a whole. It also creates a new business model enabled by the fast-growing mobile apps in our daily lives.

1. Introduction

Parking in downtown areas (or residential areas) is often a headache for both commuters and traffic managers in most large cities. Finding a parking spot and walking to work often constitutes an appreciable fraction of the total travel time. The desperate scramble for parking spots also adds to the problems of chronic congestion and choking pollution. It is also often the case that parking fees may exceed the total vehicle operating costs. The problem cannot be solved simply by continuing the construction of new parking facilities due to growing population and car ownership, particularly in cities like Hong Kong due to its high density of traffic and limited road and parking capacity. As found in the study by Shoup (2006), 30% of traffic congestion in road networks is caused when people are circulating around to find a parking spot, and about 8.1 min is spent in finding a parking spot. Ayala et al. (2011) find out that every year in Chicago, there is 63 million miles for vehicles to travel in order to find a vacant space to park, which generates 48,000 tons of carbon dioxide to the environment.

Parking management is normally considered as an integrated part of travel demand management. From this perspective, levying some road toll to the vehicle (Glazer and Niskanen, 1992; Verhoef et al., 1995; Arnott and Inci, 2006; Zhang et al., 2008 and Qian et al., 2011) is considered to be effective for simultaneously mitigating traffic congestion and regulating parking demand. Zhang et al. (2011), Yang et al. (2013) and Liu et al. (2014a,b) find out that parking reservation through

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parking permits distribution and trading are efficient in traffic management. Particularly, it is found that an appropriate combination of reserved and unreserved parking spots can temporally relieve traffic congestion at the bottleneck and hence reduce the total system cost, because commuters without a reserved parking spot are compelled to leave home earlier in order to secure a public parking spot. A recent review of parking modeling was given by Inci (2015) and a few latest studies of parking problems in a network context can be found in Boyles et al. (2015) and Zou et al. (2015).

To reduce the wastage of money and time in parking search, various smart parking systems are developed and implemented worldwide to make efficient utilization of these existing parking spots through optimal allocation of the limited parking resources by a management center. Park et al. (2008) and Panja et al. (2011) argued that the available parking spots of each parking lot should be collected to guide the commuters to the low occupancy parking areas which is so called infra structure–to–vehicle (I2V). In fact, with the fast development of smart mobile and wireless communication techniques, various applications (apps) emerge in recent years, which effectively mitigate information uncertainty on parking availability. In San Francisco, SFPark (http://sfpark.org/) puts all the information online for people to park and also uses demand-dependent parking fees to coordinate the traffic congestion in different areas. Geng and Cassandras (2013) propose a novel 'smart parking' system which is based on resource allocation and reservation both on street and off street and show that when informed, people will save quite a lot time and money and the utilization of the parking spots will increase as well, and Chen et al. (2015) discuss a smartphone-based parking reservation system to manage the limited amount of parking spaces located in a downtown area.

Shared parking (also known as gaparking from gap and parking; From Wikipedia, the free encyclopedia) emerged recently as a new notion of making more efficient use of parking facilities like for example, roverparking.com, spot-park.com, just-park.com, parkhound.com.au, parkcirca.com, etc. It uses existing gaps or spaces intended for parking cars when the owner is not using it. Availability of parking gaps for others stems from the fact that most parking spaces are only used part time by a particular driver or owner who lives in one location and works in other, and the utilization and availability patterns follow predictable daily, weekly and annual cycles. By making private parking space publicly available for rent, shared parking not only allows the owner to make additional money but also helps alleviate the aforementioned shortage of parking spaces.

Realizing the above new business opportunity and model particularly in an area with mixed commercial and residential land use developments, parking lot management companies intend to temporarily repurchase some private parking lots and sell them to public users during certain time of a day. Guo et al. (2016) is the first one to develop a simulation-optimization based decision method to determine the repurchase strategy. A Gaussian mixture model is proposed to describe the time-varying arriving/departing behaviors of drivers and meanwhile the stochastic constraints of the profit maximization problem are formulated. The expected optimal repurchase amounts and parking time are estimated via simulation optimization.

With the revolution of information and communications technology and especially the latest rise of the mobile internet, shared parking or gaparking can be simply enabled through an "e-parking platform" that can be added to the fast-growing mobile apps in our daily lives. The e-booking platform can directly connect a private parking space owner who gaparks his property when not in use with people who is searching for a place to park for certain hours. Alternatively, the e-parking platform can serve as an intermediary to collectively gather the daily or weekly availability information of private parking lots through a long-term contract with their owners. These rentable parking lots are then made available through the platform for advanced booking by those who wish to park by completing an e-form with the date and time. It works like "online-to-offline commerce" pattern, which is the most popular trend of entrepreneurship at present called O2O. A business strategy that attracts some potential consumers from online channels to offline stores like "taobao" in mainland China a transaction e-platform operated by Alibaba. Online-to-offline commerce, or O2O, identifies customers when they are browsing a webpage through some internet advertisements or promotions, and then uses a variety of attractions and approaches to solicit the customers to jump to their homepage. This type of strategy incorporates techniques used in online marketing with those used in brick-and-mortar marketing.

Like the abovementioned other intermediaries, gaparking through an e-parking platform offer the following advantages: (1) pre-allocation but booking in advance removes a degree of uncertainty between the private parking lot owners (abbreviated as O-users) and the public users (abbreviated as P-users). P-users can save time as they have a guaranteed reserved parking lot at a certain location and thus do not have to cruise for parking; yet P-users is able to choose a convenient parking lot near their destination. The O-users, on the other hand, have a guarantee of their parking lot availability upon their prescheduled return (of course, the e-parking operator can always set an occupancy buffer of each parking lot in parking allocation and/or set aside a few public parking lots to mitigate the risk of parking conflicts). (2) The P-users can save money in comparison with using commercial car parks and may gain additional discounts by booking ahead of time; By joining and selling their parking lot to the platform, the O-users can earn a certain amount of money at a small cost (e.g., due to inconvenience). (3) By charging a service fee for parking acquisition and booking, the e-parking platform operator can earn operating income (revenue net of all operating costs inclusive of the cost for protection guarantee of both O-users and P-users).

In this paper we consider advanced booking and allocation of shared parking lots. Suppose the e-parking platform operators already acquire a certain number of rentable private parking lots, each with a prespecified available time window of a day (parking supply). The platform receives requests for gaparking, each with a specific entry and leave time (parking demand). We propose a simple binary integer linear programming models to allocate the requests to specific parking lots so as to maximize the parking lot utilization or accommodate as many requests as possible under parking space and time constraints. It can be also regarded as revenue maximization under given demand and supply as well as and preset parking charge.