# Dynamic Service Management of One-Way Car Sharing Systems

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In recent years, Car Sharing (CS) businesses, like Zipcar, Autolib' and Car2go have shown significant growth and market potential. By the end of 2014 ZipCar has attracted more than 767,000 members and deployed 11,000 vehicles. Cities around the world, such as London and San Francisco, are trying to promote the development of city CS programs. The whole industry is expected to reach US $6 billion by 2020.

CS services bring benefits to users and also the whole environment as an innovative transportation mode. The pooling of shared cars help maintain the flexibility of individual driving, at the same time can achieve higher utilization of cars than privately owned vehicles, most of which remain idle for significant portions of the day. According to the survey by Loose [2], one shared vehicles, on average, can replace four to ten private cars. The potential reduction of private car ownership can deliver social and environmental benefits, e.g, mitigating traffic congestion, reducing $CO_2$ emissions due to overproduction of cars, and relaxing parking pressure. Furthermore, the centralized ownership of cars is more conducive to the adoption of new technologies and more fuel-efficient cars, due to economies of scale. For example, Car2Go deploys pure electric vehicles in the shared fleets in several cities, including Austin, San Diego and Vancouver. The deployment cost for supporting infrastructure (e.g., chargers for electric vehicles) can also be shared among a large fleet size, which reduces average costs.

In this paper, we investigate the operational characteristics of the emerging free-floating (one-way) CS service model, e.g., Car2Go, which allows users to access and return cars at any location within the service region, and hence is more viable and flexible comparing with traditional CS service, requiring cars to be picked up and returned at the same station. However this kind of flexible CS service poses new operational challenges to the firm. The imbalanced and time-variant service demand from place to place, caused by the geographical and social-economic attributes of the city, inevitably leads to vehicles being idle at locations where inbound flow exceeds outbound flow (saturated stations), and vehicle shortages at other regions (transient stations). It will be difficult to match driving demand and vehicles. Both the utilization of vehicles and service level are limited. If not addressed appropriately, the imbalance problem will hamper the profitability and growth of the business model.

Traditional repositioning operations implemented in a bicycle sharing system or other business filed are well researched. Fan *et al.* [3] consider the vehicle allocation problem within the CS network via stochastic programming. Nair and Miller-Hooks [5] use mixed-integer programming to generate redistribution plans under service level constraints. Lin and Yang [6] address deployment decisions of the bicycle sharing stations under similar chance constraints on service. Shu *et al.* [7] evaluate the utilization and value of redistribution in a bicycle sharing system. Adelman [1] uses an internal pricing mechanism to generate a control policy for accepting/rejecting demand for service units (shipping containers in their context) in an imbalanced queuing network. However, in free-floating CS systems, such operational strategies are difficult or costly to implement. Unlike bicycle sharing systems, in which bicycles can be redistributed by trucks within the city, the vehicles can only be repositioned from one station to another by employed drivers, incurring significant labor costs. Besides, the widely dispersed free-floating cars are costly to be collected and redistributed in an urban environment.

Hence, in this instance, we propose to use operational strategies that can influence users driving behavior and then mitigate the negative impact due to unbalanced flows, from a revenue management's perspective. We model the CS system by a closed queuing network as George and Xia [4], with vehicles flowing among different stations driven by users. Users' choice on whether to use service or not and vehicle returning destination are captured by a discrete choice model, which aggregately determine the flow rate between any two stations. We build a Markov Decision Process to model the firm's decision at each time epoch according to the vehicle distributions within the network. Two strategies are analyzed and compared in this paper, i.e. **dynamic service blocking** and **dynamic surcharge fees**. In the first scenario, the firm dynamically choose to block a subset of stations that a user can return the vehicle after use. Given available service regions (returning stations) that a user can reach from a specific origin station, the probability of vehicle returning within unblocked service regions are described by the discrete choice model. Due to the curse of dimension, we design an approximated dynamic programming (ADP) approach for the firm to generate state-dependent service regions dynamically. In the second case, the firm dynamically adds surcharge fees for specific stations where vehicles are picked up or returned, to influence the choice probabilities. Linear bound are derived and used to evaluate the performance of the two strategies. Finally, we test our model using Car2Go data and show potential significant profit improvement of the two methods in practice. We also numerically do economic analysis of using electric vehicles (EVs) in the shared service fleet, and the optimal proportion of EVs are determined.

# References


[1] Adelman, D. (2007). Price-Directed Control of a Closed Logistics Queueing Network. *Operations Research* 55(6): 1022-1038.

[2] Loose, W. (2010). The State of European Car-Sharing. Bunderverband CarShaing, June 2010 *Research Report*.

[3] Fan, W. D., R. B. Machemehl & N. E. Lownes (2008). Carsharing: Dynamic Decision-Making Problem for Vehicle Allocation. *Transportation Research Record: Journal of the Transportation Research Board* 2063(1): 97-104.

[4] George, D. K., & C. H. Xia (2011). Fleet-Sizing and Service Availability for a Vehicle Rental System via Closed Queueing Networks. *European Journal of Operational Research* 211(1): 198-207.

[5] Nair, R., & E. Miller-Hooks (2011). Fleet Management for Vehicle Sharing Operations. *Transportation Science* 45(4): 524-540.

[6] Lin, J. R., & T. H. Yang (2011). Strategic Design of Public Bicycle Sharing Systems with Service Level Constraints. *Transportation Research Part E: Logistics and Transportation Review* 47(2): 284-294.

[7] Shu, J., M. Chou, Q. Liu, C.P. Teo & I.L. Wang (2010). Models for Effective Deployment and Redistribution of Bicycles Within Public Bicycle-Sharing Systems. *Operations Research* 61(6): 1346-1359.