Abstract:

We consider the problem of optimal fleet sizing in a vehicle sharing system. Vehicles are available for short-term rental and are accessible from multiple locations. A vehicle rented at one location can be returned to any other location. The size of the fleet must account for randomness in demand, rental duration, and vehicle returns. We show that the dynamics of the system can be modeled using a closed queueing network and obtain explicit and closed form upper and lower bounds on the optimal number of vehicles (the minimum number of vehicles needed to meet a target service level). We show that the bounds are asymptotically exact under several regimes and use features of the bounds to construct a simple and closed form approximation that is also exact under the asymptotic regimes considered. Extensive numerical experiments show that the approximate and exact values are nearly indistinguishable for a wide range of parameter values. The approximation is highly interpretable with buffer capacity expressed in terms of three explicit terms: (1) standard buffer capacity that is protection against randomness in demand and rental times, (2) buffer capacity that is protection against randomness in vehicle returns, and (3) a correction term. Our analysis reveals important differences between the optimal sizing of standard queueing systems (where servers always return to the same queue upon service completion) and that of systems where servers, upon service completion, randomly join any one of the queues in the system. We show that the additional capacity needed to buffer against this randomness can be substantial even in systems with vanishingly small demand.

Bio:

Shining Wu is an assistant professor in the Department of Logistics and Maritime Studies at the Hong Kong Polytechnic University. His research interests include sharing economy, strategic consumer behavior, queueing theory and its applications, and data-driven optimization. He received his Ph.D. degree in Industrial Engineering and Logistics Management from the Hong Kong University of Science and Technology, and B.S. in Statistics from Peking University, China. His research has appeared in Operations Research.