Flexible Work Hour Scheme with Heterogeneous Commuters

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1 Introduction

1.1 Background

There is no doubt that home-to-work trips cause the majority of traffic congestion in the morning peak hours. The travel demand is concentrated in the morning peak periods mainly because the work schedules are highly concentrated within a relatively short period of time. Scheduling flexibility for work trips is constrained by the work hour scheme imposed by employers, the nature of the professionals (e.g., financial firms follow strict business hours), and commuters’ personal preference (e.g., chained family activities such as dropping off children at school before go to work). If the flexible work hours will not decrease the productivity of the firms and will not conflict with the schedules of the other non-work activities, the congestion caused by these work trips can be avoided by shifting the demand away from the center of the peak. Recently the Land Transport Authority at Singapore has launched the “Travel Smart” pilot programme, which provides employers incentives and consultation to influence their employees’ travel behaviour. For example, flexible work hours are allowed so that employees can choose to travel during off-peak periods. Another pilot project, New York off-peak truck program, encouraged to shift deliveries to between 7pm and 6am by providing incentive grants to participating carriers and receivers. The analyses at Holguin-Veras et al. (2011) indicate that the economic benefits of a full implementation of the off-peak delivery program in the New York City metropolitan area are in the range of 147 to 193 million per year, including the savings on travel time and pollution for regular-hour traffic as well as productivity increases for the freight industry. There are significant

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potential benefits if possibly redistribute and spread the work start times. On the other hand, empirical evidences (Wilson, 1988) demonstrate the wage variation resulting from work start time, which also reveals that the productivity varies with work start time. A few studies have further explored the equilibrium and system optimum of staggering work trips by considering the trade off between traffic congestion and firm productivity (Henderson, 1981; Takayama, 2014; Yushimito et al., 2014; Fosgerau and Small, 2014).

1.2 Previous studies

The classic bottleneck model, first proposed by (Vickrey 1969), has been extensively studied to analyze commuters travel decision choices and to formulate the peaking phenomenon in the morning rush hour (e.g., Hendrickson and Kocur, 1981; Smith, 1984; Daganzo, 1985; Newell, 1987; Arnott et al., 1990, 1994; Yang and Huang, 1997; Liu and Nie, 2011). It is assumed that commuters living at residential areas need to commute to work places at the city Central Business District along a road in morning. They have a desired arrival time, i.e., their work start time, and suffer a penalty when they arrive earlier or later than than the work start time. However, if commuters want to reach their work places at time closer to their work start time, they need to suffer higher travel delay due to peak hour congestion.

User heterogeneity have brought important improvement in modeling decision choices of heterogeneous commuters and in predicting the reliable welfare effects and benefits of public policy, e.g., congestion pricing and staggered work hours. Commuters are considered to be heterogeneous, (e.g., Cohen, 1987; Arnott et al., 1988, 1994; Lindsey, 2004; van den Berg and Verhoef, 2011; Qian and Zhang, 2013; Hall, 2013), in their value of travel time and unit cost of scheme delay, or preferred arrival time (work start time). It is well known that the closed-form solutions for the bottleneck model with user heterogeneity exist in special cases (e.g., for a small number of groups, or assumptions are imposed on how the value of time and schedule cost parameters may be correlated). If a general joint distribution of these user-specific parameters is considered, however, obtaining an equilibrium solution for bottleneck model seems analytically intractable. Recently, Liu et al. (2015) proposed a semi-analytical method for solving the bottleneck model with general user heterogeneity and the same work start time. Their approach transforms the dynamic user equilibrium (DUE)problem of the bottleneck model into an equivalent static asymmetric traffic assignment problem, which admits closed-form cost function and is subsequently formulated and solved as a variational inequality problem. Chen et al. (2015) further develop this method to solve DUE under step toll.

2 Methodology

This paper is motivated to add another important dimension of decision choices, i.e., work start time. We consider a discrete set of work hour schemes which commuters can choose from. Then we makes use of the semi-analytical approach in Liu et al. (2015) and develops a time-expanded network model for solving the dynamic user equilibrium of heterogeneous users under the flexible work hour scheme, i.e., working commuters can choose their work start time. The equivalent problem is still a static and asymmetric traffic assignment problem. Extra capacity constraints are imposed for the number of commuters traveling between two peaks. The basic idea is shown in Figure 1, where two groups of commuters make simultaneous choices of departure time and
work hour scheme. Without considering the wage variations over work start time, we assume that the participating employers only offer the flexible work hour scheme to those whose productivity will not be affected by work start time. The proposed approach is used to numerically test the redistribution of travel demand at user equilibrium which can be served as a tool to estimate the congestion reduction after implementing the flexible work hour scheme, and to guide the employers to properly stagger their work hour.

References


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