Available online at www.sciencedirect.com
SCIENCE DIRECT®

ELSEVIER

Transportation Research Part A 39 (2005) 41–60

TRANSPORTATION RESEARCH PART A

www.elsevier.com/locate/tra

Integrated scheduling of daily work activities and morning–evening commutes with bottleneck congestion

Xiaoning Zhang [a], Hai Yang [b,*], Hai-Jun Huang [c], H. Michael Zhang [a,d]

[a] *The State Key Laboratory in Road and Traffic Engineering, Tongji University, Shanghai, 200092, China*
[b] *Department of Civil Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, PR China*
[c] *School of Management, Beijing University of Aeronautics and Astronautics, Beijing 100083, China*
[d] *Department of Civil and Environment Engineering, University of California, Davis, California 95616, USA*

Received 29 October 2003; received in revised form 15 March 2004; accepted 27 April 2004

Abstract

Previous analysis of bottleneck congestion and departure time choice have focused on the trade-off between queuing delay cost and early/late arrival penalty for a given work start schedule. The actual scheduling of travel and work activities may well depend on some other important factors, such as the travel cost of the after-work trip, the work duration and the utility variation of different work times. This paper attempts to link the home-to-work and work-to-home trip schedules via the work duration. The morning home-to-work and evening work-to-home travel costs are calculated by the bottleneck queuing models and each individual's work utility is determined according to his/her work start time and end time with a predetermined marginal timing utility function. Travelers make a tradeoff between travel cost minimization and stay-at-home and work utility maximization in choosing their travel and activity schedules. A discrete choice model is used to predict the dynamic evolution process and stationary distribution of individual schedule patterns. After specifying various kinds of timing utility functions with different degrees of flexibility in work hour schemes, a set of numerical experiments are conducted and some meaningful observations are made from the experiment results, particularly on the effect of flexible work hours on traffic congestion mitigation.

* Corresponding author. Tel.: +852 2358 7178; fax: +852 2358 1534.
E-mail address: cehyang@ust.hk (H. Yang).

0965-8564/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tra.2004.04.005

Keywords: Activity analysis; Timing utility; Travel schedule; Bottleneck congestion; Staggered work time

1. Introduction

Modeling departure time choice of morning commute is essential to understand and predict how congestion arises from individual travel decisions. The specific questions that require answers often involve how individuals adjust their travel schedules in response to the occurrence of congestion and congestion–mitigation measures, such as improved accessibility, pricing, flexible work hours and traffic information provision. In this context, the interplay between travel time and activity schedule arrangement is recognized to be critical in the activity based travel demand analysis. Previous studies in this area have been largely involved in bottleneck/network real time congestion, daily variability in departure time choice, timing utility of various activity patterns, trip chaining and activity duration.

The interests of transportation researchers for the analytical aspects of bottleneck congestion and departure time choice can be traced back to the sixties. Vickrey (1969) considered a single bottleneck connecting a residential area to a city center and derived the departure time pattern based on an optimization rationale for individual commuters. Users are assumed to perform deterministically to balance the trade-off between schedule delay and travel time. A subsequent stream of papers followed the topic continually kept up to date (Hendrickson and Kocur, 1981; Smith, 1984; Daganzo, 1985; Braid, 1989; Small, 1992; Arnott et al., 1990, 1993; Yang and Huang, 1997; to name but a few). The peak-load congestion of a road bottleneck was also modeled when there is a substitute travel mode or route, such as in Tabuchi (1993), Braid (1996), Danielis and Marcucci (2002), Huang and Yang (1999) and Huang (2002). Yang and Meng (1998) made a further extension by simultaneously dealing with departure time, route choice and congestion tolls in a general queuing network with elastic demand. An essential feature of the deterministic bottleneck congestion models is to allow for endogenous trip scheduling in trading off congestion cost and schedule delay.

Instead of modeling traveler's behavior in a deterministic manner, discrete choice models based on random utility theory have been applied to analyze peak-period congestion and trip scheduling with uncertainty (Small, 1982; Hendrickson and Plank, 1984; Ben-Akiva et al., 1984, 1986; Wilson, 1989). More recently, discrete choice models of departure time choice have been extended to account for travel time reliability (Noland and Small, 1995; Bates et al., 2001). Alternative approaches to the bottleneck congestion and morning commuting pattern are proposed by Henderson (1974) and Chu (1995) who applied a speed-flow relation to determine time-varying tolls on a congested road, by Mahmassani and Herman (1984) who considered the dynamic user equilibrium with joint selection of departure times and routes, and by Huang and Yang (1996) who modeled the time varying pricing of a congested network of parallel routes with elastic demand using optimal control theory.

In the meantime, there is a vast accumulation of the literature in the study of scheduling of part or whole daily activities. Lerman (1979) and Kitamura (1983, 1984) modeled the trip chaining behavior in activity scheduling using disaggregate choice models. The micro features of the interdependence between activity and travel choices have been computationally modeled and empiri-