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Valuing Travel Time Reliability: Individual, System and Dynamic Perspectives

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A Thesis Submitted for the Degree of Doctor of Philosophy

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Outline

Traffic congestion is a widespread social problem and needs to be alleviated by sophisticated management and investment. The technological advances in monitoring traffic conditions allow the stochastic features of travel time to be better captured, which leads to many new schemes on managing the risk of travel time and thus potentially large benefits to users of transport system. To account these benefits, this dissertation is dedicated to the theoretical framework in including travel time variability (unreliability) into cost-benefit analysis, with a particular focus on the monetary value attached to unit improvement of travel time reliability.

Chapter 2 reviews the theory of cost benefit analysis, the methods for estimating value of travel time variability and the existing travel demand modules. The main findings are summarized as below. Although the logsum approach is gradually gaining popularity by its theoretical superiority, Rule-of-Half (RoH) is still the standard toolkit for implementing cost-benefit analysis (CBA). In both case, the estimation Value of Travel Time Variability (VTTV) are critical for delivering reliable prediction of travel demand. The scheduling preferences is a generalized version of schedule delay costs which allows time-varying marginal utilities at origin and destination. This generalization can better accommodate the preferences of flexible workers, and sometimes lead to consistent TTV measures more convenient for real-network application. However, this sort of VTTVs is derived from the single-traveler utility maximization problem, so it is only suitable to be applied to cases without dramatic change of congestion profile. The stochastic-network traffic assignment, provided that VTTV is carefully calibrated is a simple and reasonable tool to serve as travel demand module in CBA.

Chapter 3 is particularly concerned with estimation of the cost of travel time variability. It analyzes how systematic perception errors in travel time distribution might bias the estimates and undermine the theoretical equivalence between the scheduling model and mean-dispersion model. We estimate a scheduling model based on rank-dependent expected utility using the data collected in a stated-preferences experiment and calculate the derived cost of travel time variability. The results indicated that (i) travelers are mostly pessimistic, (ii) the scheduling preference estimates are biased (around 20%) without considering probability weighting in a risky choice situation, and (iii) the cost of probability misperception may be as little as 1% or as large as 8%, depending on how the marginal utility of time varies by the time of day and the unobserved heterogeneity. The perception error does contribute to the empirical gap of scheduling model and mean-dispersion model, but only to a limited level.

Chapter 4 investigates the system (social) cost when travelers are constantly searching for lower travel cost while the transport system are constantly facing random shocks. Taking travel time variability as given, we use a stylized departure-time equilibrium approach to study how system cost of a traffic bottleneck (point queue model) varies with travel time variability when congestion profile depends on traveler's collective behavior. We find that the cost of travel time variability is the same with exogenous or endogenous congestion when commuters are mostly flexible worker. In this case, cost-benefit analyses of travel time reliability improvements yield consistent results even if departure time adjustments are not accounted for. Otherwise if most commuters are inflexible workers, departure time adjustments decrease congestion, which strongly mitigates the cost of travel time variability. We provide a new price variable, Social Value of Travel Time Variability (SVTTV) to replace VTTV in this case in order to account for the departure time adjustment.

Chapter 5 challenges the feasibility of equilibrium analysis for deriving the system cost of travel time variability. We argue that the system might not have a stable equilibrium in some cases and that travel time variability is a phenomena of traveler's day-to-day behavior adjustment rather than a pure input. We use simulation to investigate how much travelers' day-to-day departure time adjustment contributes to the travel time variability and the time-average travel cost in a long run. It reveals that equilibrium analysis is likely to overestimate the marginal benefit of capacity expansion and lead to over-investment of transport infrastructure. It also implies that, when researcher infer VTTV from the real behavior, cautions should be taken if equilibrium state is a necessary assumption because the market might not act as assumed.

Chapter 6 concludes the main results and discusses the future works, such as relating travel time variability to urban structure or replacing the point queue model with more realistic congestion technologies.