Endogenous scheduling and the cost of travel time variability

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Urban congestion is a significant burden in most developed economies. Congestion is not only associated with delay itself, but also with delays that are random and unpredictable for travelers. This random travel time variability is quite significant, and the delay on bad days can easily exceed undelayed travel time itself. It is then clearly of interest to assess the economic cost of travel time variability.

The prevailing literature assigns value to random travel time variability based on the notion of scheduling preferences, given by a utility function that depends on the departure time and on the arrival time of a trip, see Börjesson et al. (2012), Fosgerau and Karlström (2010), Fosgerau and Engelson (2011), Engelson and Fosgerau (2011), Noland and Small (1995), Tseng and Verhoef (2008). In the context of the bottleneck model, De Palma and Fosgerau (2011) discuss a general form. These papers are based on the idea of a traveler facing random travel time and choosing departure time to maximize expected scheduling utility. Scheduling utility is taken to be exogenous, being independent of the distribution of travel time. Any externalities associated with the traveler being delayed are ignored.

It is, however, not clear that it is reasonable to treat scheduling preferences as exogenous. On the contrary, it is quite conceivable that scheduling preferences are affected by the distribution of travel time when the trip is for an appointment that is made in the knowledge of the distribution of travel time. If a traveler knows that travel time is uncertain, then she will take that into account not only when she decides when to depart but also when she makes the appointment. Taking into consideration that a traveler might be on his way to a meeting of some kind also makes it clear that there is an externality associated with the arrival time, which concerns the effect on another person participating in the meeting.

This paper develops an economic model for the scheduling of a meeting between two people. The basic mechanism driving the model is a fundamental property of physical meetings, namely that a meeting cannot start until at least two participants are present.

We begin by setting up a model of choice of departure time to a meeting where the utility of the meeting cannot be accumulated until a colleague arrives. Both colleagues are assumed to derive utility at decreasing rates from the previous activity and at constant rates from the meeting. The case of deterministic travel time is then analyzed, showing that the meeting mechanism gives rise to a continuum of Nash equilibria. A relevant equilibrium refinement in the deterministic case is that Pareto dominated Nash equilibria will not be played (Nash, 1950), and this refinement singles out a unique equilibrium. The same pattern of equilibria is obtained when the two colleagues' travel times are fully correlated such that the difference in their travel times is still deterministic. Hence, the relevant aspects of travel time variability are fully captured in the variations in the disparity between the two colleagues' travel times.

Next, we develop the case where the travel time disparity is random and absolutely continuous. In this case, it turns out that there cannot exist more than one Nash equilibrium. A unique equilibrium exists if and only if the sum of the ratios of utility rates of the previous activities to the utility rates of the meeting tends to a number smaller than 1 as the time tends to infinity. A small random tremble added to the travel time disparity leads either to non-existence of Nash equilibrium or to a unique Nash equilibrium that is different from the Pareto dominant equilibrium with a deterministic travel time disparity. The equilibrium with this tremble (if it exists) has systematically higher cost than the Pareto optimal equilibrium under deterministic travel time disparity, and the difference may be interpreted as the cost of stochasticity of travel time disparity per se. With fixed mean travel times, the equilibrium cost for each traveler is an increasing function of the scale of random disparity of travel times.

The private and social marginal costs of travel time variability are then derived. Our model allows an interpretation where scheduling preferences arise endogenously, and where these preferences depend on the assumed behavior of the person to be met. If an analyst decides to measure the scheduling preferences of one of the participants after the meeting has been agreed, then these preferences will be endogenous. We use this observation to compare to what is found in previous literature. We find that the marginal social cost of travel time variability for a traveler about to meet another person can reach as much as twice the cost we would infer based on the scheduling preferences of the traveler if the other person's behavior were taken as exogenous. Conversely, we also find that when the two travelers' travel time distributions are highly correlated, then a unilateral increase in one's travel time variability can actually reduce cost, if the result is a reduction in the variability in the travel time disparity. A brief review of empirical travel times indicates that correlation among travel times on neighboring but not coinciding routes will rarely be sufficiently high for this to be the case.

Our findings suggest that for cities where travel time variability has a heterogeneous incidence across the network, due to the coordinating behavior of colleagues, the benefits of reducing variability can be particularly high on routes that are used by a substantial minority of the population. However, if a strong majority uses the same route, then due to this same coordination behavior, the benefits of reducing its variability may be moderate.

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