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Commuting for meetings ☆

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ABSTRACT

Urban congestion causes travel times to exhibit considerable variability, which leads to coordination problems when people have to meet. We analyze a game for the timing of a meeting between two players who must each complete a trip of random duration to reach the meeting, which does not begin until both are present. Players prefer to depart later and also to arrive sooner, provided they do not have to wait for the other player. We find a unique Nash equilibrium, and a continuum of Pareto optima that are strictly better than the Nash equilibrium for both players. Pareto optima may be implemented as Nash equilibria by penalty or compensation schemes.

1. Introduction

Urban traffic congestion is a significant burden on developed economies. As most people know from experience, the costs of congestion are not only related to the (average) delay. The difficulty or even impossibility of predicting travel time is also an inherent feature of urban congestion and should be taken into account by economic analysis.[1]

Many efforts to incorporate the cost of random delays into policy assessment have drawn on a model of preferences regarding the timing and duration of a trip. Such scheduling preferences were first introduced in Vickrey (1969, 1973) with Small (1982) providing the first empirical estimates. [2] This has led to a substantial literature on the value of random travel time variability. This literature considers a traveler about to undertake a trip where the travel time is random; he chooses departure time to maximize expected utility, where utility depends on the departure time and the arrival time. It is then possible to examine how indirect utility depends on the distribution of random travel time.[3]

When we take into consideration that a traveler might be on his way to a meeting of some kind, it becomes clear that there are interactions involved that seem quite important. There are many situations where this is relevant. We can think of meetings at work, appointments with friends and family, a date with a potential partner or generally any situation where people have to meet. These interactions are overlooked by the literature just reviewed, which takes the perspective of a single individual.

We develop an economic model for a meeting between two people. The model describes two players each initially engaged in some activity from which they each derive utility at a declining rate. Each must choose a departure time from his activity, and after a random travel time with known distribution each arrives at the meeting. The players only derive utility at the meeting after both have arrived, and thus waiting for the other player is costly. Players choose departure time to maximize their payoff, the expected utility.[4] We consider Nash equilibrium where neither player has

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[1] Random delays are often related to traffic incidents such as accidents. According to one estimate (Schrank and Lomax, 2009, Appendix B, p. B-27), incident-related delays alone contribute 52–58 percent of total delay in urban areas in the United States. On bad days, delay can easily be as large as undelayed travel time itself (Fosgerau and Fukuda, 2012).

[2] Vickrey (1969, 1973) introduced two specific forms of scheduling preferences in the context of the bottleneck model, de Palma and Fosgerau (2011) discuss a general form.

[3] See, among others, Noland and Small (1995); Bates et al. (2001); Fosgerau and Karlstrom (2010); Fosgerau and Engelson (2011); and Engelson and Fosgerau (2011).

[4] This is a kind of coordination game. The standard coordination game has discrete strategy set, whereas the strategy set here is continuous.

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Nomenclature

A_i	random arrival time for individual i
d_i	departure time for individual i
d_i^*	Nash equilibrium departure time for individual i
F, f	CDF and PDF for Δ
i, j	individuals from the set $(1, 2)$
h_i	marginal utility of individual i spending time at the origin
r_i	response function for individual i
S	difference in departure times, $d_1 - d_2$
T_i	random travel time for individual i
U_i	utility for individual i
u_i	expected utility for individual i
w_i	marginal utility for individual i spending time at the meeting
X_i	standardized travel time for i
Y	standardized difference in travel times
α_i	individual i's earliness compensation
β_i	individual i's lateness penalty
Δ	random variable for the difference in travel times, $T_2 - T_1$
μ	mean of the difference in travel times, Δ
λ_i	parameter in the first-order condition for Pareto optimum
μ_i	mean travel time for individual i
ρ_{ij}	correlation coefficient of travel times for individuals i and j
σ	standard deviation of the difference in travel times, Δ
σ_i	standard deviation of travel time for individual i
Φ	a part of the function for payoffs under Nash equilibrium

incentive to change departure time given the departure time of the other and compare this to the set of Pareto optima.

Our findings may be summarized as follows. We find that Nash equilibrium exists in our model and is unique. A player's payoff depends on the joint travel time distribution of both players. Specifically, payoffs are non-increasing in the variance of the difference of travel times, which means that not only the variance of the individual travel times but also their correlation matters. These conclusions are natural but do not arise in the extant literature discussed above. Moreover, there is a continuum of Pareto optima in the model, and these Pareto optima correspond one-to-one to the probability that the first player is late. Nash equilibrium is not Pareto optimal, and there exists a continuum of Pareto optima that yield strict increases in payoff for both players relative to Nash equilibrium. With penalties to each player for arriving later than the other, it is possible to implement any Pareto optimum as a Nash equilibrium. Some Pareto optima may also be implemented through a scheme that compensates players for waiting for the other.

These results have implications that seem not to have been discussed before. First, evaluation of measures to reduce travel time variability could seek to take into account the interaction with other people than the travelers who are directly affected, namely those who might be waiting for the travelers when they arrive late. Second, there might be occasions where alternative policy measures have different effects on the distribution of travel times within a city. In such cases, the present results suggest that measures that have greater effect on the variance of *differences* in travel times for different transport corridors should be given more emphasis, ceteris paribus. Finally, employers could conceivably implement penalty or compensation schemes for their employees that lead to a Pareto optimum as the Nash outcome, where the penalty or compensation depends on the difference in arrival times.

As the variability of the difference of travel times matters in our model, it is relevant to examine empirically the joint distribution of travel times for different travel relations. Since it is necessary to use data at the level of trips and not just roads, data requirements for a comprehensive empirical analysis are quite severe and we have not been able to find relevant studies in the literature. Instead, Appendix B provides a cursory examination using data from cameras installed on major arterial roadways in the Stockholm urban area. We have identified nine pairs of paths having cameras at both ends, each pair having different upstream locations and a single downstream location in the city center. The paths are rather short, but are the best we could find. Using data from the a.m. and p.m. peaks of all weekdays from September and October, during 2005 to 2007, we produced the table shown in Appendix B. The data reveal substantial travel time variability with a standard deviation of travel time ranging up to 75% of the mean travel time. The correlation within pairs ranges widely from −0.4 to 0.4, indicating that it would be clearly inadequate to assume travel times to be independent in order to compute the variance of the travel time difference.

Our model does not comprise the concept of a designated meeting time. The basic mechanism driving our model is the most fundamental property of in-person meetings, namely that the meeting does not in fact occur until both participants are present. The present model is the simplest we can conceive that comprises this mechanism. Extending the model with a designated meeting time requires some other elements to be included as well. In particular, there must be some penalty (e.g. accounting for embarrassment) for being late relative to the meeting time, and there must also be some mechanism for agreeing on a meeting time. Hence, including a designated meeting time would be a significant complication of the present model.

Our model is related to Ostrovsky and Schwarz (2006), who consider a manager who schedules simultaneous production processes of random duration where it is costly if the processes do not finish at the same time. Assuming independent random activity durations and linear costs for arrival earlier or later than the last completed activity, they characterize the socially optimal target arrival times in terms of the probability of arriving last, and they show how a penalty for last arrival can be determined that internalizes the total cost and results in the most efficient target arrivals. In contrast, the present paper considers individually rational agents facing trips with dependent durations and non-linear costs for early departure.

Basu and Weibull (2003) discuss the habit of punctuality in the context of choosing departure time for meetings with random travel times. They find that two stable Nash equilibria can arise, where either both persons are punctual or both tardy, and they conclude that the same society may be caught in a punctual or in a tardy equilibrium. The strategy set in their paper consists of the two strategies, the punctual and the tardy, and it is that discreteness which leads to multiple equilibria. In our paper, the strategy set is continuous, and this leads to just one equilibrium.

Our model does not represent congestion but merely takes a consequence of congestion, travel time variability, as given. By the same token, we have no congestion externality in our model. Our model could conceivably be used to extend models of congestion.