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Public transport reliability and commuter strategy

Guillaume Monchambert *, André de Palma

Ecole Normale Supérieure de Cachan, 61 avenue du Président Wilson, 94235 Cachan, France

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ABSTRACT

We consider the modeling of a bi-modal competitive network involving a public transport mode, which may be unreliable, and an alternative mode. Commuters select a transport mode and their arrival time at the station when they use public transport. The public transport reliability set by the public transport firm at the competitive equilibrium increases with the alternative mode fare, via a demand effect. This is reminiscent of the Mohring Effect. The study of the optimal service quality shows that often, public transport reliability and thereby patronage are lower at equilibrium compared to first-best social optimum. The paper provides some public policy insights.

1. Introduction

Despite increasing pollution and congestion in cities, cars remain the most popular mode of transport. Therefore, improving alternative modes of transport and making them attractive is essential in an urban context. Even if travel time is presented as the main determinant of trip characteristics, Beirao and Cabral (2007) have shown that increasing the service quality remains an important determinant of public transport demand. Several studies strongly suggest that reliability (understood as punctuality) of public transport is crucial to leverage the demand (Bates et al., 2001; Hensher et al., 2003; Paulley et al., 2006; Coulombel and Palma, in press), and in their qualitative review, Redman et al. (2013) claim that reliability is the most important quality attribute of public transport for users.

Although there is a long literature about road reliability, a sensitive lack of research is observed in public transport field (Bates et al., 2001). Some studies highlight a valuation of road reliability (Bates et al., 2001; Fosgerau and Karlström, 2010), others underline the importance of public transport comfort (Palma et al., 2013) or punctuality (Jensen, 1999), but only few deal with reliability in analytical way. A meeting of two persons has been analyzed in the context of game theory by Fosgerau et al. (2014). Public transport imposes specifications that will be exploited here.

This paper focuses on the two-way implication between punctuality level of public transport and commuter behavior. On one hand, the transportation lack of punctuality plays an important role in the modal shift as commuters may incur extra-cost due to waiting time, arriving late or missing the bus. On the other hand, Mohring (1972) has pointed out that scheduled urban public transport is characterized by increasing returns to scale. According to the Mohring Effect, as transportation patronage increases, the operator tends to improve the frequency of service and to provide external benefits due to reduced waiting times and denser transit network. Demand is also influential in the service quality offered, and the bus company may adapt its punctuality to the level of potential demand. We show that some users may decide to arrive late at the bus stop when punctuality is low. As a consequence, the bus company itself may become less strict as far as the punctuality. In a nutshell, this means that user behavior (punctuality of users) is influenced by the punctuality of public transport. These mechanisms may generate a vicious circle: lateness of some agents calling for lateness of the other agents.

* Corresponding author. Address: Ecole Normale Supérieure de Cachan, Laplace 302, 61 avenue du Président Wilson, 94235 Cachan, France.

E-mail addresses: guillaume.monchambert@ens-cachan.fr (G. Monchambert), andre.depalma@ens-cachan.fr (A. de Palma).

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In this paper, we study three situations: (i) the reaction of the bus company when it faces a higher price of the alternative mode, (ii) the gap between the bus punctuality at equilibrium and at optimum and (iii) the equilibrium versus optimal modal split when punctuality matters. In particular, we show that when the alternative mode fare raises, the resulting increase in bus patronage makes the bus operator improve the bus punctuality. This mechanism can be considered as an application of the "Mohring Effect".

We consider a duopoly which symbolizes a modal competition between public transport and another mode, which we call taxi. The attention is focused on the monetary impacts of punctuality. We simplify aspects related to engineering. A duopoly is used because determinants of demand for public transport are related to the demand for private transport (Balcombe et al., 2004). Usually, the public transport firm is not profit maximizing because it is regulated and because it receives subsidies. Some intermediary cases arise when the firm receives fixed subsidies and wishes to maximize its revenues and minimize its costs. In order to guarantee good enough quality of service, the subsidy may depend on the quality of service offered. Such incentives are more generally used when public resources are scarce. Two different types of variables are observed in the model: the public transport punctuality level, which is selected by the bus company and the prices set by the bus and taxi companies. Both have a substantial influence on demand for public transport (Paulley et al., 2006). Unreliability has a strong negative impact as it implies excessive waiting time and uncertainty (Wardman, 2004; Paulley et al., 2006).

We insist on the fact that even if along the paper we consider the alternative mode as a taxi company, the analysis may easily be extended to the private car. In fact, one has to only consider the taxi fare as an exogenous variable which stands for the variable cost of using a car. An increase in taxi fare can also be interpreted as a rise in gas prices.

Considering commuting trips, preferences can be analyzed with the dynamic scheduling model. In this model, individuals' preferences reflect agents' tradeoff between travel time, early schedule and late schedule delays. Commuters may choose different strategies to minimize their trip cost. This theory has been first introduced by Vickrey (1969) and then renewed by Arnott et al. (1990). Such analysis is usually specific to road analysis (Fosgerau and Karlström, 2010); here we introduce waiting time to extend this model to public transport. Incidentally, note that the French State-owned railroad (SNCF) suggests to reschedule work arrival and departure times in order to reduce congestion (Steinmann, 2013).

Commuters are differentiated by their preferred arrival time at workplace and by their residential location, which is measured as the time to travel to their destination when using the alternative mode. Two different preferred arrival times are considered, and the location is uniformly distributed among commuters.

The analysis for the model proceeds in three steps. The first step consists in finding out the modal choice of commuters depending on prices and punctuality for the public transport and the alternative mode. The second step determines which price and punctuality levels are set by companies at equilibrium given the behavior of commuters identified in step one. The third step is to assess the prices and the punctuality level that minimize the total social cost and to compare these results with the ones derived in step two.

Our model is here applied to road modes, but it can be generalized to other transport modes which face delays, such as inter-city rail or air transport. More generally, the modeling approach is relevant for any service concerned with reliability.

The paper is organized as follows. Section 2 describes the model and the commuter's strategies. Section 3 considers equilibrium and its properties. The gain due to the transition from equilibrium to optimum is analyzed in Section 4. A numerical application is provided in Section 5 to illustrate our results and to present some public policy insights. In Section 6, we propose an extension by assuming that a second bus arrives shortly after the first one. The final section concludes and provides directions for further research.

2. Punctuality in public transport

We consider a unique route from an origin A to a destination B with households living alongside this route. Every morning, all commuters have to reach the point B which can be viewed as the CBD of a city. The route is measured in time units and is Δ hours long. A unique bus line and a taxi company serve the CBD by using this route and bus stations are uniformly distributed alongside this route.

As both modes are road modes, they endure the same traffic conditions. Therefore, we do not take into account congestion on the road. Moreover, the road congestion has no impact on the modal split. Thus, both modes have the same speed, and we refer to a bus stop located at δ hours from the CBD as "bus stop δ". For example, the bus stop Δ is located at the border of the city. Similarly, all commuters live along the route, and we refer to commuters who need δ hours to reach the CBD, whether they use the bus service or the taxi service, as "commuters δ". For each $\delta \in [0;\Delta]$, all commuters δ live at the same place (see Fig. 1).

The commuters are divided into two groups according to their preferred arrival times: the first type of commuters (referred to as *Group A*, which includes a part θ of the population) would rather arrive at time *T*, and the second one (referred to as *Group B*) at time $T + x$ (see Fig. 2). This reflects the fact that even though a majority of commuters wishes to arrive at work place at the same time, not all commuters have the same preferred arrival time. Commuters locations are uniformly distributed among each group in the same manner (Fig. 2) and the distribution is assumed to have a support $[0;\Delta]$ so that $F(0) = 0$ and $F(\Delta) = 1$.

For analytical tractability, we consider a single bus. However, this model can be easily adapted to other modes of public transport that run on a schedule. The bus is scheduled to arrive at the CBD at a given time, but it may be late. The probability of lateness is not random: the bus company selects its quality service level and applies it in the same manner along the route. Thus, when the bus company chooses to be late, it is late along the whole journey, and its lateness is constant over time. Commuters are aware of the punctuality level and adapt their behavior accordingly. In particular, they might arrive at the bus stop after the scheduled time even if there is a risk to miss the bus by doing so. This late arrival can occur rationally because there is a waiting cost for users. Commuters optimize their tradeoffs between cost of waiting time, schedule delay, and a cost corresponding to the use of an alternative mode, which in our model is the taxi. A commuter may either select taxi *ex ante* or use the taxi if he misses the bus.

It should be stressed that the taxi service represents all private transport modes. From user perspective, the taxi fare is not different than the variable cost of his own car.

Table 1 introduces notations used in this paper and their numerical values that will be used in Sections 2, 5 and 6. We first characterize the network and then the commuter behavior. Finally, we characterize the modal split.

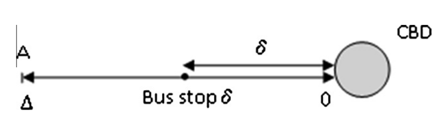

Fig. 1. The route from home to CBD.