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Route choice in the presence of a toll road: The role of pre-trip information and learning

Florian Knorr [a,*], Thorsten Chmura [b], Michael Schreckenberg [a]

[a] Physik von Transport und Verkehr, Universität Duisburg-Essen, 47048 Duisburg, Germany
[b] Nottingham University Business School, Nottingham, UK

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ABSTRACT

Choosing a route is a complex task, especially since the roads' capacities are limited and road users non-cooperatively seek to optimize their own trip. This article present the results of three in-laboratory route choice experiments. In all experiments the participants had to choose repeatedly between a high-capacity toll-road and a toll-free main road. We investigate the role of pre-trip information on the resulting route usage dynamics. Besides the absence of a stable equilibrium point (Wardrop's User Equilibrium), we found that the participants improve their decisions over the course of time as a result of learning. Additional information appears only useful if only a limited number of participants possess such information. Moreover, we found gender-related differences in the observed road usage patterns: female participants were more likely to choose the toll road than male participants.

1. Introduction

Driving a vehicle constantly requires making decisions: should I change lanes? is it safe to accelerate? which route is best for the home-to-work commute? The latter question is interesting for several reasons: Of course, to some extent it is a question of personal preference what constitutes a good trip (Albert, Toledo, & Ben-Zion, 2011; Zhang & Levinson, 2008). Yet, among the factors affecting the perceived trip quality 'travel time' has been found to be the most important one (Hall, Wakefield, & Al-Kaisy, 2001; Papinski, Scott, & Doherty, 2009). This quality measure is very intuitive as travel time is considered as "lost" time. This loss can even be quantified in money terms: an early study from 1999 (Small, Noland, Chu, & Lewis, 1999) estimated the value of each hour traveled between $ 2.6 and $ 8.1. More recent studies (Brownstone & Small, 2005; Cirillo & Axhausen, 2006) estimate the value of travel time between $ 10 and $ 20 per hour. This range is consistent with the USDOT's guidance on the valuation of travel time in economic analysis (Belenky, 2011).

When travel time serves as the primary criterion to assess a trip, choosing the best route is a very difficult task. For the traffic conditions (e.g., free flow or congestion) change over time. Therefore, a currently uncongested road may be blocked when we finally reach it. Advanced traffic information systems (ATISs) such as on-board navigation devices might make things even worse. By providing information on the current traffic state and route capacities, congestion and travel times may increase instead of decrease—especially if the provided information is incomplete (Arnott, de Palma, & Lindsey, 1991; Mahmassani & Jayakrishnan, 1991; Noland, 1997). A congestion warning for a critical road segment, for instance,

* Corresponding author. Tel.: +49 203 379 3901; fax: +49 203 379 6564.
E-mail addresses: florian.knorr@uni-due.de (F. Knorr), thorsten.chmura@nottingham.ac.uk (T. Chmura), michael.schreckenberg@uni-due.de (M. Schreckenberg).

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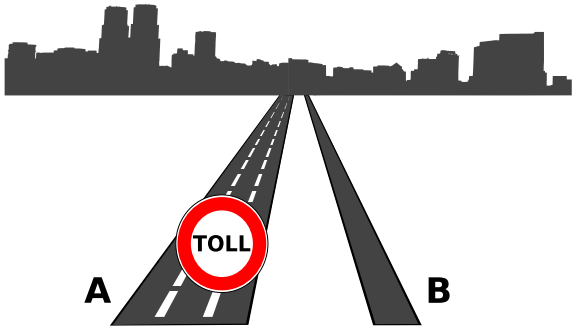

Fig. 1. The experiment from the participants' perspective. They were in the position of a tripmaker facing a commute downtown, and they could choose between a high-capacity toll-road (A) and a toll-free, low-capacity main road (B). The travel time on the selected road depends on the total number of participants choosing the same road.

may act as a self-destroying prophecy; when all drivers choose alternative routes to avoid the critical road segment, the latter may be free of congestion, whereas the alternative, formerly uncongested routes become congested.

A common approach to ease congestion is adding more capacity to congested corridors by adding more lanes to existing roads or by constructing new ones (Schrank, Lomax, & Eisele, 2011). Modern approaches even envision the application of information and communication technologies for the same purpose (Knorr, Baselt, Schreckenberg, & Mauve, 2012; Lakas & Chaqfeh, 2010). These strategies can be combined with introducing tolls for the newly added infrastructure. In this context, it is interesting to ask how drivers react to such a route choice scenario. Do they find an "equilibrium" strategy of which road to use, and, if they do so, how long does it take to find such a strategy. Does additional information improve their choice?

Unfortunately, there is lack of empirical data investigating the impact of traffic information on route choice. A very common approach of collecting such data is by conducting commute surveys (Abdel-Aty, Kitamura, & Jovanis, 1997; Mahmassani, Caplice, & Walton, 1990; Mannering, Kim, Barfield, & Ng, 1994). Thereby, the results represent rather a snapshot of the current situation. Therefore, its explanatory power in terms of the temporal evolution of decision processes, the role of learning, and the interaction between road users is quite limited. Besides, there is always the risk that the respondents adapt their answer to what they believe is right or favorable (cf. the halo effect) (Schofer, Khattak, & Koppelman, 1993). Hence, laboratory experiments have become a valuable tool to study dynamics of the route choice process in a controlled environment (e.g., Helbing, Schönhof, & Kern, 2002; Selten, Schreckenberg, Pitz, Chmura, & Wahle, 2003, 2007). Furthermore, laboratory experiments offer the possibility of paying the participants and coupling their pay-off to the success of their decisions. This financial incentive makes laboratory experiments much closer to reality because in reality a bad route choice costs time and/or money, too.[1]

In this article we want to investigate the influence of traffic information on route choice behavior by presenting the results of three laboratory experiments—each with more than 100 participants. In all experiments the participants had to choose repeatedly between two routes, a so-called main road and a toll road. Yet, the information provided to the participants before making their choice varied. Similar to Selten, Chmura, Pitz, Kube, and Schreckenberg (2007), the participants were assigned a fixed starting balance, and they lost the more money the more participants chose the same road. Naturally, selecting the toll road led to an additional, demand-independent fee. The benefit of the toll road was that it had a higher capacity and, therefore, an increased demand resulted in a slower increase of the resulting travel time and expenses.

2. Experimental setup

The experiment, which was programmed and conducted with the software z-Tree (Fischbacher, 2007), mimicked a realistic route choice scenario (The participants' instructions can be found in Appendix A): all participants were assigned to role of motorists who repeatedly had to travel to the same destination (e.g., the home-to-work commute). For their trip, they could choose between two roads—a toll road and a toll-free main road (see Fig. 1). The toll serves here as a deterrent[2] to choose this road (de Palma & Lindsey, 2000). (In the context of congestion pricing, such deterrent effects are used to control

[1] Before designing our experiments, we have contacted a company operating a German toll road, and we asked for their experience with surveys. They told us that they used surveys before opening the toll road to determine (a) how many respondents would be willing to use the new toll road, and (b) which price they would be willing to pay. After the opening of the toll road, significantly less drivers than expected used the toll road as the hypothetical situation of a survey did not compare to the actual situation of choosing the toll road. Hence, the monetary gains/losses in our experiments are a very important aspect regarding the results' transferability to reality.
In this context, however, it has to be noted that the participants of our experiments received a starting balance from which the travel expenses were deducted. Therefore, the participants left the experiment with more money than they started with, whereas in real life travel expenses are unavoidable and actual "losses".

[2] Although tolling makes a road less attractive to drivers, this does not mean that the public opinion is per se against tolling and road pricing. The analysis of international surveys on road pricing and tolling (Kriger, Shiu, & Naylor, 2006) revealed a more sophisticated public opinion.