Transportation Research Part A 70 (2014) 294–310

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

On the value of highway travel time information systems

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ARTICLE INFO

Article history:
Received 10 August 2012
Received in revised form 3 October 2014
Accepted 13 October 2014
Available online 20 November 2014

Keywords:
Departure time selection
Route choice
Unreliability costs
Travel time uncertainty

ABSTRACT

After the widespread deployment of Advanced Traveler Information Systems, there exists an increasing concern about their profitability. The costs of such systems are clear, but the quantification of the benefits still generates debate. This paper analyzes the value of highway travel time information systems. This is achieved by modeling the departure time selection and route choice with and without the guidance of an information system. The behavioral model supporting these choices is grounded on the expected utility theory, where drivers try to maximize the expected value of their perceived utility. The value of information is derived from the reduction of the unreliability costs as a consequence of the wiser decisions made with information. This includes the reduction of travel times, scheduling costs and stress. This modeling approach allows assessing the effects of the precision of the information system in the value of the information.

Different scenarios are simulated in a generic but realistic context, using empirical data measured on a highway corridor accessing the city of Barcelona, Spain. Results show that travel time information only has a significant value in three situations: (1) when there is an important scheduled activity at the destination (e.g. morning commute trips), (2) in case of total uncertainty about the conditions of the trip (e.g. sporadic trips), and (3) when more than one route is possible. Information systems with very high precision do not produce better results. However, an acceptable level of precision is completely required, as information systems with very poor precision may even be detrimental. The paper also highlights the difference between the user value and the social value of the information. The value of the information may not benefit only the user. For instance, massive dissemination of travel time information contributes to the reduction of day-to-day travel time variance. This favors all drivers, even those without information. In these situations travel time information has the property that its social benefits exceed private benefits (i.e. information has positive externalities). Of course, drivers are only willing to cover costs equal or smaller than their private benefits, which in turn may justify subsidies for information provision.

1. Introduction and background

For a number of years, one of the objectives of many traffic agencies around the globe has been the development of Advanced Traveler Information Systems (ATIS) on highways, and in particular the dissemination of travel time information to drivers. The boom of information and communication technologies, in short the ITS (Intelligent Transportation Systems), has opened up new possibilities, not without huge investments in surveillance and dissemination technologies (e.g.

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http://dx.doi.org/10.1016/j.tra.2014.10.005
0965-8564/

increased loop detector density, installation of Automatic Vehicle Identification systems, ..., Variable Message Signs, on board navigation devices, Smartphone applications, ...) (see Turner et al., 1998 for a comprehensive review). In general, the accuracy of travel time estimation is directly related to the intensity of surveillance and to the level of technological development of the measurement equipment, although significant research efforts have been made to improve this relationship (Soriguera et al., 2008). In spite of this, one has to bear in mind that, in real-time information systems, some degree of information uncertainty is unavoidable, even with a perfect travel time measurement. This responds to the fact that real-time information, actually, is a short term prediction with intrinsic uncertainty (Soriguera and Robusté, 2010).

The costs of installing such information systems are known by traffic agencies. They explicitly pay for them. The benefits obtained, however, are not reported in such quantitative terms. It is usually claimed that travel time information is the most valuable traffic information for drivers (Palen, 1997), because it allows for making better decisions (e.g. route, mode and departure time selection) and it reduces the uncertainty drivers face. These vague statements regarding the benefits, although qualitatively true, should not be enough to justify the required investments. Furthermore, they do not help in achieving more efficient implementations. The quantification of the value of travel time information systems as a function of the system design parameters should be the objective. This would allow assessing their benefit/cost ratio and defining trade-offs leading to better designs and increased system efficiency (e.g. technology selection, precision requirements, corridor prioritization, assessment of the dissemination strategy...).

Some studies have dealt with this quantification of benefits using stated preferences surveys (see Khattak et al., 2003 for an extensive review) or revealed preferences observations (Tseng et al., 2013). In (Walker and Ben-Akiva, 1996) for example it is found that travelers would be willing to pay up to $0.50 per trip for convenient and accurate travel time information. Though this type of approach may give some indication of the user value of information (although not accounting for its social value) it is insufficient to address the previous objectives. Much more detail is required. This is confronted in the other common approach, and adopted in the present paper, based on the cost-benefit conceptual framework. The value of information is defined as the reduction in the trip costs resulting from its knowledge (Chorus et al., 2006; Ettema and Timmermans, 2006; Levinson, 2003; Arnott et al., 1991). Benefits of precise information include the reduction of travel times (e.g. as a result of an optimal route choice for a given departure time, or a rescheduling of the departure time) and the reduction of uncertainty, which may imply further reductions in trip costs. These benefits are not limited to their users (i.e. the user value) but might be extended to all drivers, even to those uninformed (i.e. the social or external value of information). These positive externalities appear when the modified behavior of a significant portion of informed drivers affects positively to the overall performance of the highway. For instance, a massive dissemination of information contributes to the reduction of the travel time variability across routes and times of the day, improving the reliability of the highway system, for all drivers. On the contrary, the possibility that very bad information (i.e. very bad precision, partial or irregular information, etc) raises trip costs for all drivers should not be taken lightly (Arnott et al., 1991).

In order to account for all the benefits of information, it is necessary to recognize that not only average delays imply costs to the driver. Travel time uncertainty (or synonymously, travel time unreliability) caused by the existence of variable day-to-day delays, also entails high costs (Small, 1982; Noland and Small, 1995; Bates et al., 2001; Bates, 2001; Lam and Small, 2001; Noland and Polak, 2002; Asensio and Matas, 2008; Fosgerau and Karlström, 2010; OECD, 2010). Uncertainty implies, simultaneously, probabilities of arriving too late and of arriving too early. Both situations result in an extension of the lost time (at destination or en-route), with the aggravating circumstance of missing meetings, connections or incurring other lateness penalties in case of arriving too late. To prevent the latter, drivers allow extra time for the journey (i.e. a buffer time), increasing the probability of arriving too early (Cirillo and Axhausen, 2006). As travel time uncertainty increases so does the total lost time, because of the extension of the buffer times or the delays on route. It is proven in Fosgerau and Karlström (2010) that considering the simplest model to introduce risk aversion and for any given and fixed travel time distribution, the scheduling costs grow linearly with the mean lateness and with the standard deviation of travel times. In addition, even in the unlikely situation of being exactly on time, the anxiety and stress caused by the uncertainty imply a cost for the driver. It is reported in Ettema and Timmermans (2006) that the sum of all these scheduling costs due to travel time uncertainty may account for 20–40% of the generalized trip costs. 15% is reported in Fosgerau and Karlström (2010), and values between 12 and 50% are found in the present paper (see Section 4). The costs of uncertainty, although frequently overlooked, are clear.

The concept of travel time unreliability refers to the driver's inability to accurately forecast how long his trip will last. Following (Bates, 2001; OECD, 2010), travel time is defined to be unreliable when random factors may have an impact on the duration of the trip, such that the actual arrival time differs from the desired one. This definition implies that predictable or expected variations (e.g. regular commuters expect average recurrent congestion at peak hours) do not contribute in the unreliability of the highway. A direct consequence of these definitions is that the unreliability level of a particular infrastructure does not only depend on its total travel time variability but also on the ability of drivers to predict travel time variations. Better knowledge implies less unreliability. This knowledge can be gained through experience. This is the reason why the unreliability levels that sporadic drivers face are higher than regular commuters. Alternatively, travel time information also improves the predictability of travel times. This means that information not only reduces stress, but also unreliability costs.

The better knowledge gained by means of travel time information, affects differently the two types of trip decisions that could be modified. On the one hand, there are operative decisions, which can be made at a given instant, in real-time, because they do not affect the sequence of scheduled activities. Route choice and acceptance or not of park&ride options (in round trips) are, in general, examples of operative decisions. On the other hand, there are decisions that need to be planned in advance, like the departure time choice. It is more difficult to modify planned decisions, because changes affect