The values of travel time and reliability with automated vehicles

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Abstract

Advancement in mobile devices is allowing airline and public transit passengers to undertake useful and productive work activities while travelling. Car passengers are also bracing for the introduction of automated vehicles which could relive them from driving and allow them to perform other activities while travelling. The potential productive utilisation of in-vehicle time is not considered in the theory of the value of time where time spent travelling is treated as a 'wasted time'. In this paper, we extend the theory of the value of time to analyse car commuter's optimal allocation of time among different activities and the implication of allowing a productive use of in-vehicle time on the valuation of travel time and reliability. We showed the existence of an optimal time allocation and found the value of travel time and reliability declining with an exogenous improvement in the productivity of in-vehicle time if the commuter is not highly risk averse. Results in the paper also indicate that, in the absence of binding time constraints, individuals will be unwilling to pay for a reduction in travel time and an improvement in reliability if in-vehicle time is as productive as time out of the vehicle. This has important implications in economic appraisal of investments in transport infrastructure and productivity enhancing technologies.

1 Introduction

The theory of the value of time (e.g. Johnson, 1966; Oort, 1969) considers time spent travelling as a 'wasted time'. As a result, a reduction in trip duration frees up time that can otherwise be used to perform useful private activities or productive work. Often, the monetary value of the reduced travel time along with gains in improved reliability provide the main economic rationale for spending a great deal of public resources on transport infrastructure. The treatment of in-vehicle time as a pure waste of time is likely to change in the future as continued improvement in mobile devices and gradual introduction of automated vehicles could make it possible to work or carry out useful private activities while travelling. Time spent travelling will be worth some value if it becomes possible to perform activities while travelling. Advances

in mobile devices and increased access to internet on flights are allowing airline and public transit passengers to perform enjoyable and gainful activities while travelling. The car industry too is promising to relieve drivers from driving thereby enabling them to use in-vehicle time for alternative use.

This paper analyses the implication on the value of time and reliability of technologies that make it possible to carry out activities while travelling that substitute for activities elsewhere, at home or at work. The need to account for the possibility for utilisation of time spent travelling on other activities has been indicated in a recent round-table discussion among leading experts on the subject (ITF, 2019). To this end, we expand the standard framework in the literature to allow for a possible productive or enjoyable use of in-vehicle time and the implication this has on the valuation of travel time and reliability.

We built a model that examines how a commuter allocates his or her time budget among different activities where some of these activities can only be carried out at home or work while others can be performed at either location and while travelling. We showed existence of an optimal allocation of time and examine how the values of travel time and variability change with the possibility of productive use of in-vehicle time.

The contribution of this paper is twofold. First, it provides a theoretical framework based on consumer choice to examine the effect of mobile communication devises and automated vehicles on car commuter's valuation of reduced travel time and unreliability. While this has been analysed previously in few empirical studies, our model can serve as a foundation for future research. Secondly, by allowing the possible productive utilisation of in-vehicle time, the model presented in the current paper provides an alternative way to control traffic congestion.

We showed the existence of an optimal time allocation and examined how the values of travel time and reliability change with changes in the productivity of in-vehicle time. Allowing for a productive use of in-vehicle time has led to a lower value of travel time and that the reduction in the value of travel time equals the value accruing to the commuter had travel time not been reduced. This is a new insight compared to previous literature (e.g. Johnson, 1966; Oort, 1969; DeSerpa, 1971). Results in the paper further imply that the values of travel time and reliability decline with increased automation of vehicles and advances in other technologies that make travel more convenient and enhance the usefulness of in-vehicle time if commuters are not very risk averse. We found that, in the absence of binding time constraints, individuals will be unwilling to pay for a reduction in travel time and an improvement in reliability if in-vehicle time is as productive as time out of the vehicle. This has important implications in economic appraisal of investments in transport infrastructure and productivity enhancing technologies. Similar results can be found in the literature. For instance, de Jong and Kouwenhoven (2019) found a 20% reduction in the value of travel time for public transit passengers resulting from improved comfort and enhanced productivity of travel time. Likewise, Molin et al. (2020) found a 30% reduction in the value of travel time as commuters in their survey were provided with the possibility of conducting activities while traveling. While this finding is not new, we derived the result from a behavioural model and showed that it holds in general within the framework of our model.

2 The model

We consider a commuter who begins a typical workday at home and who has to take a trip to a workplace, where he or she finishes the day. The commuter intends to optimally allocate his or her time budget of T time units among leisure, work and a *mobile activity*, which involves a set of leisure and work activities that can be undertaken while travelling. If L and W respectively denote the quantity of time assigned to leisure and work, the amount of time available to carry out the mobile activity is given by $m = T - (1-\alpha)t_t - W - L$ where t_t is travel time. We assume that the commuter is fully productive when performing the mobile activities at home or at work but may be less so while travelling. This is controlled by a parameter $\alpha \in [0,1]$ such that the effective units of the mobile activity undertaken is $M \equiv T - (1-\alpha)\, t_t - W - L$.

The commuter's preferences are represent by a utility function: $U(W, L; \alpha, t_t)$, which is assumed to be increasing and concave. For a given travel duration, the commuter will allocate his or her total time among different activities to maximise utility subject to the constraint that time spent on different activities cannot exceed the total available time and consumption G does not exceed income:

$$\begin{aligned} &\max_{W,L} U(W, L, M; \alpha, t_t) \\ \text{subject to } & t_t + W + H \leq T \quad (\lambda) \\ & G \leq \omega(W + \theta M) \quad (\kappa) \\ & W, L \geq 0 \end{aligned} \tag{1}$$

where ω is the wage rate; θ is the share of work in the mobile activity and λ and κ respectively are time resource and consumption constraints. In contrast to conventional work-leisure optimisation problems such as Oort (1969) and DeSerpa (1971), our model accounts for a potential productive use of travel time and any displeasure from travelling per se as long as the displeasure is reflected in terms of reduced productivity of in-vehicle time. In addiiton, the models by Becker (1965) and Johnson (1966) can be shown to arise as a special case of our model where travel time is unproductive.

With random travel duration, we assume the commuter allocates the time budget across activities in view of a known travel time distribution and that the optimal allocation is determined sequentially. Firstly, departure time and leisure are determined for a given (W, t_t) and then working hours are chosen conditional on the choice of leisure and realisation of travel time. We solve the utility maximisation problem by backward induction. We have shown the existence of an optimal allocation and discussed its characteristics.

3 Main findings

- An exogenous reduction in travel time and its variability are beneficial suggesting that the commuter would be willing to pay some amount for travel time savings. The resulting values of travel time and reliability depend on the productivity of in-vehicle time and whether the commuter has binding time constraints.
- When travel time is unproductive, the value of travel time equals the marginal value of time at work. This result has been indicated previously with the expression for the value of travel time comprising the wage rate (Becker, 1965; Johnson,

1966; Oort, 1969); the subjective value of work (Johnson, 1966) and the value of reduced displeasure from travelling per se (Oort, 1969).

- Allowing for a productive use of travel time in our model has led to a lower value of travel time. The reduction in the value of travel time equals the value accruing to the commuter had travel time not been reduced. This is a new insight compared to previous literature (e.g. Johnson, 1966; Oort, 1969). While a reduction in travel time releases time that can be used more productively elsewhere, this comes at the expense of lost value as in-vehicle time is worth some value. This was disregarded in previous studies as in-vehicle time was considered unproductive. Thus, to the extent that the displeasure from travel is reflected in reduced productivity of in-vehicle time and the subjective value of time is accounted in our specification, the value of travel time in the current study would be lower than implied elsewhere in the literature. Thus, accounting for the potential productivity of in-vehicle time has led to a lower value of travel time.
- If travel time is as productive as time at work/home and the time constraint is non-binding, then the value of travel time is zero. Thus, the commuter will be unwilling to pay for a reduction in travel time. This is so since, under those circumstances, there is no alternative usage of greater value to which the released travel time will be reallocated. In practice, a zero value of travel time is unlikely as restriction in in-vehicle space and similar other factors may keep in-vehicle time relatively less productive than time at work or home. If the constraint is binding, however, then the value of travel time is positive even if travel time is fully productive. This is so since, in this case, more time is allocated to the mobile activity than desired.
- The value of travel time declines with the productivity of in-vehicle time if the commuter is not highly risk averse. The dependence on the extent of risk aversion arises due to potential reallocation of time across activities and the changes in the 'effective' quantity of time available to individual activities induced by changes in travel time and its productivity. While the above result had previously been indicated in empirical studies (e.g. de Jong and Kouwenhoven, 2019; Molin et al., 2020), we derive the result from a behavioural model and showed that it holds in general within the framework of our model. The theoretical prediction in our model and aforementioned empirical evidence imply that the value of travel time is expected to decline over time as the introduction and development of automated vehicles allow travellers to conduct enjoyable and worthwhile activities while travelling.
- An exogenous improvement in reliability is beneficial and, if in-vehicle time is as productive as time at work or at home, then the value of reliability will be zero even if the commuter has binding constraints. If in-vehicle time is as productive as time at work, then there is no alternative use of in-vehicle time providing better value and hence the value of reliability will be zero. This is a new insight compared to previous literature, in which the value of reliability is positive and depends on (a) the marginal value of time at work (e.g. Fosgerau and Engelson, 2011) or the marginal cost of being early or late for work (e.g. Fosgerau and Karlström, 2010); and (b) the distribution of travel time or some feature of this distribution.

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