The cost of travel time variability for air and car travellers

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6 Conclusion

This study developed methods to assess the cost of travel time variability for air and car travellers. As Table1.1 in Chapter 1 shows, the cost of travel time variability can be determined in three steps. First, researchers need to develop a behavioural micro economic model that is able to capture travellers' responses to travel time variability. Second, this model needs to be validated and calibrated using empirical data. Third, the model needs to be applied using observed or simulated travel time data in order to see how large the costs of travel time variability are.

Each of the chapters in this thesis contributes to at least one of these steps. The behavioural models are extensions of the scheduling model of Noland and Small (1995). In these models, travellers dislike arriving at a different time than their preferred arrival time. They anticipate travel time variability by leaving earlier from home or choosing an earlier flight, and therefore the dynamic choice of the traveller is incorporated in an intuitive way. Chapters 2 and 5 make use of discrete choice econometric methods to estimate the cost of arriving early and late for air travellers going to the airport, and for car commuters participating in a real world reward experiment. Chapters 2, 3 and 4 apply the models using observed travel time data.

In Chapter 2 we analysed the cost of travel time variability for air travellers going to the airport. We analysed the effect of airport access travel time variability on access travel cost. The mixed logit estimations show that scheduling plays an important role in departure time decisions of travellers going to the airport. For both business and non-business travellers there is heterogeneity in the scheduling parameters. A connection was made between the estimated shadow cost of scheduling and equilibrium user cost, taking into account anticipating departure time choice of air travellers. Using a dataset of Dutch travel times we showed that for business travellers the cost of variability are in the range of 0-30% of expected access travel cost, depending on the time of day. For non-business travellers this share is in the range of 0-25%. The high percentages correspond to the peak hours and there is a strong relation between the cost of travel time variability and average travel time cost. These numbers are somewhat higher than the values found by Fosgerau and Karlström (2010), who analysed the cost of travel time variability for commuters, but are comparable to the values found by Peer et al. (2010) for Dutch car travellers.

Chapter 3 analyses the cost of arrival delay variability for air travellers. We showed that air travel delay variability for US domestic air travel may increase the expected user cost of delays of air travellers, with our central estimate being 27%. Given our assumptions on scheduling preferences, on the generalised price for other cost components than delays, and on the values of schedule delay, we view this as a conservative estimate. We showed that for the 40% busiest origin-destination pairs in the US, expected user cost from air travel delays can be well approximated as a linear function of the mean delay, which considerably simplifies applications of the models in policy analysis, at least for the cases that would leave the relation itself intact.

Chapter 4 shows how probability weighting affects departure time decisions of car travellers and develops a rank dependent scheduling model. Using the concept of probability weighting we are able to derive the costs of likelihood insensitivity, optimism and pessimism. If the parameterised probability weighting function for car travellers is similar to what has been found in the literature on choice under risk, then we find costs of probability weighting ($COPW$) for car travellers in the morning peak that are on average around 3 per cent. This low number is due to the fact that travellers overweigh the probabilities of both good and bad outcomes. Therefore, on average they do a good job in choosing their optimal departure time from home. We show that this result is rather robust for different assumptions on the WTP values. This result questions whether there is a strong need for models that estimate probability weighting functions, given the complicated nature of these models, and the low relevance for policy evaluation that the 3% figure suggests. This figure, however, naturally changes when the probability weighting function changes; for the ranges of parameters we tested, we found the cost of probability weighting in the range of 0 – 24 per cent. Therefore, for extreme probability weighting, the cost of probability weighting may still be substantial.

Chapter 5 estimates a scheduling model for car travellers using a semiparametric estimation technique called local maximum likelihood estimation. We analyse heterogeneity related to observable individual characteristics and show how to estimate a semiparametric distribution of preferences, given the assumption that more similar people in terms of socio-economic characteristics have more similar preferences. The model is applied to a stated choice experiment designed to measure the willingness to pay for travel time savings and arriving at the preferred arrival time at work. We find that there is substantial observed heterogeneity and that the estimation procedure explains the data significantly better than fully parametric regression techniques. The proposed method has the advantage that the heterogeneity of preferences is related to observed characteristics and therefore it is easier to apply in long-term forecasting in transport models, since in the long-run populations may change. Furthermore, the estimation approach works well for small datasets.

In order to provide policy makers a good perspective on the value of reliability, several lessons can be learned from this study. First, excluding the benefits of improved reliability in CBAs may lead to a significant underestimation of user benefits from infrastructure investments. Current transport project appraisal should therefore include indicators for the benefits of increasing reliability.

Second, our study suggests that the cost of travel time variability is strongly related to the mean travel time delay. Although policy makers should be aware of the fact that the cost of travel time variability do depend on the time of the day, it seems that the cost of travel time variability is strongly related to increases in travel delay. For policy measures that do not break the relationship between the mean and the standard deviation of travel times, the mean delay multiplied by a fixed factor can be used as a proxy for the cost of travel time variability. Policies that improve the mean delay, such as road capacity expansions, will also reduce the cost of travel time variability.

Third, current estimates of the value of time obtained from simple time/money trade-offs might be biased if researchers do not account for scheduling cost. Longer travel times will lead to an earlier departure or a later arrival, and therefore these simple trade-offs also capture a part of scheduling cost of the traveller.[1] In these SP studies researchers should clearly indicate if a longer travel time comes with an earlier departure time or a later arrival time. Because scheduling cost are ignored in these experiments, it may be that SP values obtained from simple time/money trade-offs are upward biased.

Fourth, estimates of the value of time for air travellers based on revealed preference data may be upward biased if scheduling is not accounted for. Chapter 4 shows that expected scheduling cost is strongly related to the mean arrival delay, and therefore revealed preference estimates of the value of time will likely pick up the expected scheduling cost. As argued before, this might not be a problem for evaluation studies as long as the user cost can be approximated by the mean delay.

Fifth, travel time variability cannot simply be measured by the standard deviation of travel times, but is defined by the information set of the traveller and the full distribution of travel times that does depend on the time of the day. The latter is captured appropriately in our study, but study of the information set is an important issue that should not be neglected. If drivers are well informed about the current travel situation and have knowledge about for example weather and incidents, the cost of travel time variability is lower than what is estimated in this study and other studies in the literature.

Small and Verhoef (2007) stated that:

"The theory of time allocation is well developed and permits us to rigorously address conceptual issues concerning value of time and reliability. Despite uncertainty, a consensus has developed over many of the most important empirical magnitudes for values of time, permitting them to be used confidently in benefit assessment. Another decade should bring similar consensus to value reliability" (Small and Verhoef 2007, p.55)

The literature seems to be reaching a consensus that scheduling models are able to capture travel decisions of travellers facing variable travel times in an appropriate and realistic way. However, it is as yet undecided which scheduling model to use, and more empirical research is needed to analyse which model describes the preferences of travellers in the most appropriate way.

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[1] In the Small (1982) model of scheduling cost *departing* earlier has no cost, in the Tseng and Verhoef (2008) model it has.

One of the things that this thesis confirmed is that for policy evaluation, approximations of the cost of travel time variability may be available. Chapter 2, 3 and 4 show that the cost of variable arrival times is strongly related to the cost of mean travel times. This is because travel time variation increases if the mean travel time increases, and therefore the mean and the standard deviation of travel times are strongly related (Peer et al., 2010; Fosgerau, 2010).

Future large scale studies may investigate this relationship in more detail and might provide policy makers approximations that easily can be implemented in CBAs. Chapter 3 shows that at least for ex-post evaluation this is a useful approach. Applying the models using observed travel time data may also help to decide which topics are of key importance in determining the cost of travel time variability. For example, Chapter 4 shows that probability weighting is probably not that important for CBAs since it only increases the cost with 3%.

The models that are developed in this thesis have of course limitations and there are several research challenges that may be addressed in future studies. Some of these were discussed in the foregoing chapters already, but we will highlight a couple of these here.

First, it is assumed that travellers have a perfect knowledge of the empirical travel time distribution. It is likely that this knowledge is related to experience. For commuters, perfect perception may be a realistic assumption, because these travellers are experienced. But for air travellers it may well be that travellers do not know the empirical travel time distribution, and therefore make larger perception errors. Also for mode choice this may be important since the perception of travel times of the non-chosen modes may be biased.[2] This may result in non-optimal behaviour, and therefore the cost of variable travel times may be higher than what was estimated in Chapter 2 and 3.

Second, we ignored trip timing decisions in transport chains. For example, Rietveld et al. (2001), De Jong et al. (2003) and Jenelius et al. (2011) study the cost of variable travel times in trip chains and tours. Although the analysis may complicate because of waiting times at intermediate stops, the essence of the optimization problem remains similar since travellers still face stochastic arrival times (Bates et al. 2001).

[2] See for example, Van Exel and Rietveld (2009), for recent empirical evidence that car travellers overestimate public transport travel times.

A third interesting topic for further study is the definition of the travel time distribution and the role of information. Throughout this thesis it is assumed that travellers have no information about the current traffic situation. For air travellers this may be an appropriate assumption since they usually cannot reschedule easily since the ticket is booked in advance. A recent revealed preference study by Tseng et al. (2010), suggests that car travellers use information about the current traffic situation. This means that the 'true' variability of travel times is likely to be lower since travellers are better informed about the current traffic situation than is assumed than in this study. Future research should address in more detail what the information set of the traveller is, and base the measure of variability conditional on this information set. This is a challenging topic, not in the least place because the information set is endogenously determined by the preferences of travellers.

Fourth, most studies that estimate scheduling models heavily rely on stated preference data. Due to improvements in GPS and license-plate recognition technology, revealed preference data becomes more widely available. The validation of stated preference estimates of value of time and schedule delays is of key importance in future research because these estimates may suffer from hypothetical bias (Brownstone and Small, 2005; Börjesson, 2008; Börjesson, 2009; Hensher, 2010). The study of door-to-door travel time variability is interesting, and may be enhanced by future data availability using GPS or phone-tracking techniques.

Fifth, the theory of decision under risk and uncertainty is well developed and some topics deserve more attention in the transport literature.[3] For example, uncertainty aversion has not been studied in detail, while this may be particularly relevant for revealed travel behaviour. Transport economists should seek a balance between developing more detailed behavioural models and the application of these models in policy analysis. More detailed models may help to understand the decision process of the traveller better, but are not necessarily needed for policy evaluation as we showed in Chapter 3, because the effects on user cost may be small. An important question that still is unanswered is if the recently found estimates for reference dependence and probability weighting are due to the

[3] See for an overview of recent important contributions: Abdellaoui et al. (2011).

artefacts of stated choice experiments, or are properly capturing the revealed behaviour of travellers (De Borger and Fosgerau, 2008; Hjorth, 2011; Hensher and Li, 2010).

Sixth, it is worth studying the effect of omitting scheduling cost in simple time/money trade-offs in stated preference analysis. If rescheduling is not accounted for, it is likely that the value of travel time savings in these experiments is upward biased.

These and other topics deserve attention and hopefully this thesis inspires future researchers to study the cost of travel time variability with better models and better data. This to provide policy makers a convincing economic perspective on the value of reliable transport systems. This thesis is a small step forward, but probably we need another decade to arrive at a consensus about empirical values of the cost of travel time variability. That is not a problem, but a great challenge.