Authors' Response to Reviews of

Evaluating the Impacts of Parameter Uncertainty in a Practical Transportation Demand Model

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RC: ***Reviewers' Comment***, AR: Authors' Response, ☐ Manuscript Text

We are grateful for the reviewer's comments on this manuscript. We address each point in turn, with text added to the manuscript in blueand ~~text deleted from the manuscript in red~~. We address each

1. Reviewer #2

1.1. Introduction

RC: ***This manuscript presents a detailed investigation into the impacts of parameter uncertainty in a practical, trip-based transportation demand model using the Roanoke Valley Transportation Planning Organization (RVTPO) model as a case study. By employing Latin Hypercube Sampling (LHS) to explore parameter variations and their impact on traffic forecasts, the research addresses a critical issue in transportation modelling: the robustness of parameter uncertainty in realistic scenarios. In sum, the study provides a clear methodology and robust results, showing that parameter uncertainty has a minimal effect on traffic volumes in this specific model. The findings contribute to the understanding of uncertainties in transportation demand forecasting and their implications for decision- making in infrastructure planning. From the point of view of relevance and originality, I think the paper tackles a timely topic, as accurate transportation demand forecasts are essential for policy and infrastructure planning. It particularly focuses on parameter uncertainty, a less explored but highly impactful area within transportation modelling literature.***

AR: We are grateful for the reviewer's positive comments on the originality and timeliness of this research.

1.2. Literature Review

RC: ***While the literature review covers a broad range of studies, it could be more focused. For instance, the review mentions several papers that primarily address input data or model form uncertainties, which are less relevant to the paper's primary focus on parameter uncertainty. A deeper dive into recent studies specifically addressing parameter uncertainty in trip-based models or activity-based frameworks would strengthen the contextual relevance.***

AR: We agree with this general point, but feel it is important to highlight that research has largely been focused on things other than parameter uncertainty, which we identify in the paper's Introduction as the only element of modeling addressed by classical statistics.

1.3. Methodology

RC: ***I also consider that the methodology employed by the authors to assess parameter uncertainty is comprehensive and adequate. Their use of Latin Hypercube Sampling (LHS) to construct hundreds of combinations of parameters across a plausible parameter space allows for a more efficient sampling of the parameter***

space compared to simple random sampling, ensuring that the entire range of possible values is explored. This is a notable strength, as well as their evaluation across multiple trip purposes and the inclusion of high- volume and low-volume network links, to provide a comprehensive sensitivity analysis. The authors also introduced substantial changes to implied travel impedances and modal utilities based on the sampled parameter combinations, allowing them to observe the effects on traffic volume forecasts.

AR: We are glad that the reviewer found this to be a strength of the paper, and we agree that it leads to the strongest contribution of the paper.

1.4. Results

RC: ***In my opinion the results are well-structured, with clear presentation in tables and graphs. The conclusion—that parameter uncertainty contributes minimally to forecast variation compared to network and model constraints—is supported by quantitative evidence. In fact, the study's findings suggest that efforts to address uncertainties in travel forecasting may be better spent on improving model specifications and input data accuracy rather than focusing solely on parameter uncertainty.***

AR: We are happy that the reviewer found our results persuasive in light of the evidence we submit.

1.5. Minor Comments

1.5.1 Practical Impacts

RC: ***The abstract effectively summarizes the study, but including a line on the practical implications of the findings would enhance its appeal.***

AR: We welcome this advice and have revised the abstract,

> Using Latin hypercube sampling to construct several hundred combinations of parameters across the plausible parameter space, we introduce substantial changes to implied travel impedances and modal utilities, on the order of 10 percent variation. However, the aggregate effects of of these changes on forecasted traffic volumes is small, with a ~~variance~~ variation of approximately 1 percent on high-volume facilities. It is likely that in this example — and perhaps in others — the ~~static~~ network assignment places constraints on the possible volume solutions and limits the practical impacts of parameter uncertainty. Nevertheless, parameter uncertainty may not be the largest contributor to error in practical travel forecasts. Further research should examine the robustness of this finding to other less constrained networks and to activity-based travel model frameworks.

1.5.2 Coefficient of variation

RC: ***The paper assumes a coefficient of variation (CV) of 0.10 for parameter uncertainty. While the authors justify this with a rational range for value of time, the choice could be further validated with sensitivity tests or references to empirical studies. In Table 3, the coefficient of variation for non-motorized and transit trips is substantially higher than for auto trips. This observation could be highlighted and discussed in the results section to emphasize differences in confidence across modes.***

AR: We unfortunately do not have the resources to conduct an additional sensitivity analysis, which we agree would be valuable. We have, however, revised this paragraph to include an additional external reference in the literature,

> With the trip-based model described above, MC and LHS methods were used to develop alternative parameter sets to evaluate uncertainty. To identify a standard deviation for each parameter, we asserted a coefficient of variation ~~was used. A set coefficient of variation of 0.10 was used for~~ $c_v = 0.10$ the four mode choice coefficients and the destination choice parameters~~. The~~ ; the mode choice constants ~~were kept the same~~ remained fixed across all iterations. Literature had identified a coefficient of variation of 0.30 ~~,~~ (Zhao and Kockelman, 2002), but for this analysis that caused an unrealistic value of time, and thus it was changed to be 0.10~~(Zhao and Kockelman, 2002)~~. Value of time is a ratio in units of money per time that should be compared to the regional wage rate ~~. Using a~~ and was generally on the order of 10 dollars per hour in the early 2010's (Abrantes and Wardman, 2011), when the RVTPO choice coefficients were developed. A c_v of 0.30 ~~the~~ implied a value of time ~~range was~~ extending from \$2 to \$32 ~~/hr, whereas using~~ per hour, whereas a c_v of 0.10 ~~the range was~~ implied values between \$6 to \$14 /hr~~. The latter seemed more rational because it is related to wage rates and thus a c_v of 0.10 was used for our analysis~~, which we assess as more reasonable for this context. The standard deviation ~~was~~ for sampling the parameters was therefore equal to 0.10 multiplied by the mean, where the mean values in this situation are the base scenario parameters (as identified in Table 2).

AR: To be specific, the Abrantes and Wardman reference contains a meta-analysis of value of time studies conducted in the United Kingdom. Basically all mean values are concentrated around 10 UK pence per minute, which is effectively equal to dollars per hour. Considering

$$1\,\frac{\text{pence}}{\text{minute}} \times \frac{60\text{ minutes}}{\text{hr}} \times \frac{\text{pound sterling}}{100\text{ pence}} \times \frac{1\text{ USD}}{0.65\text{ pound sterling}} \tag{1}$$

where the equivalence between pounds and dollars is based on purchasing power parity (data from OECD).

1.5.3 Limitations

RC: ***The authors note that the RVTPO model's size and constraints may limit the generalizability of the findings. However, further discussion on how these limitations impact other models, especially in large urban or multimodal contexts, would add depth.***

RC: ***[moved up from below] The findings are based on a specific trip-based travel demand model, which may not be applicable to all contexts or regions. The results might vary significantly in different geographic areas or under different modelling frameworks, such as activity-based models.***

AR: We agree that an additional limitation is warranted, and we have added this to the conclusions,

> In general, these findings are based on a specific trip-based travel demand model, which may not be applicable to all contexts or regions. The results might vary significantly in different geographic areas or under different modeling frameworks, such as activity-based models. Attempting this research again with a variety of models and geographic regions would be a valuable research priority.

1.5.4 Future research

RC: ***The conclusion section could expand on how these findings might influence future research priorities or practical applications in urban transportation planning.***

AR: We have revised the conclusions section to address future research in this area, In this research we had only the estimates of the statistical coefficients, and therefore had to assume a coefficient of variation to derive variation in the sampling procedure. It would be better if model user and development documentation more regularly provided estimates of the standard errors of model parameters. ~~Even better~~ The ideal would be variance-covariance matrices for the estimated models, enabling researchers to ensure that covariance relationships between sampled parameters are maintained. Future research might reconsider the present expermiment but allowing for correlation between parameter values.

1.5.5 Equation and figure discussion

RC: ***Certain equations, such as those describing mode and destination choice, could benefit from additional explanation or context to ensure accessibility to readers unfamiliar with specific modelling practices. Figures, while generally effective, could include more explicit labels or annotations for non-specialist readers. Figure 3 on trip density by mode is insightful but could be paired with more textual analysis to discuss patterns by trip purpose or link volume.***

AR: We attempted to re-word the description of the mode and destination choice sections to render them more generally understood,

The utility equations for the mode choice model are as follows:

$$U_{auto} = \beta_{ivtt} * X_{auto} + \beta_{tc} * \beta_{ac} * X_{dist}$$
$$U_{nmot} = k_{nmot} + 20 * \beta_{wd} * X_{nmot}$$
$$U_{trn} = k_{trn} + \beta_{ivtt} * X_{trn}$$

~~These utilities are used to calculate the MCLS by:~~

$$MCLS_{ij} = \ln\left(\sum_{k\in K} e^{U_{ijk}}\right).$$

If the distance was greater than 2 miles, non-motorized travel was excluded ~~.~~

as an option. In general, modes with longer times receive lower probabilities and therefore lower proportions of trips. These utilities are used to calculate the MCLS by:

$$MCLS_{ij} = \ln\left(\sum_{k\in K} e^{U_{ijk}}\right). \tag{2}$$

This logsum value is then used as the primary impedance for a destination choice model (Ben-Akiva and Lerman, 1985). ~~Destination choice estimates travel patterns based on mode choice, trip generators (workers and households~~

The destination choice model estimates the numbers of trips between origin and destination pairs using the size of the destination (number of attractions), accessibility by multiple modes (in the MCLS),

1.5.6 Other sources of uncertainty

RC: ***The study primarily addresses uncertainty related to mode and destination choice parameters, without exploring the statistical uncertainty in trip production estimates. This omission could mean that other significant sources of uncertainty affecting traffic volumes are not adequately considered.***

AR: This is correct, and has been noted as a limitation.

RC: ***[moved up from below] Finally, the paper does not delve deeply into other sources of uncertainty, such as input data inaccuracies or model specification errors, which could also significantly impact forecasting accuracy. A more comprehensive analysis of these factors could provide a fuller understanding of the uncertainties involved in transportation demand modelling.***

AR: Again, we agree with this statement and have acknowledged it in the conclusion discussion.

1.5.7 Static assignment constraint

RC: ***The research suggests that the static network assignment may constrain the possible volume solutions, potentially limiting the practical impacts of parameter uncertainty. This raises questions about the generalizability of the findings to more dynamic or less constrained network scenarios.***

AR: While we did say this, the real constraint comes not from the particular static user equilibrium assignment but from the highway capacities themselves: there are only so many routes one can use to drive through a city, regardless of where the trips are destined. We have expanded this in the conclusions,

> given that lower trip rates may lead to lower traffic volumes globally, which could not be "corrected" by the ~~static user equilibrium assignment.~~ traffic assignment. Second, a different methodology of sampling might have produced a different result at the extremes than the results of LHS. Additionally, the relatively sparse network of the RVTPO model region — lacking parallel high-capacity highway facilities — may have meant that the ~~static network assignment~~ network assignment process would converge to a similar solution point regardless of modest changes to the trip matrix. If the number of paths between nodes is limited and constrained by highway capacity, there are only so many solutions to any highway assignment process. It may be that in a larger network with more path redundancies ~~,~~ or more alternative transit services the assignment may not have been as helpful in constraining the forecast volumes.