Uncertainty calculation in transport models and forecasts.

Transport projects and policy evaluations are often based on transport model output, i.e. traffic flows and derived effects. However, literature has shown that there is often a considerable difference between forecasted and observed traffic flows. This difference causes misallocation of (public) resources, hence resulting in socio-economic losses. Along with technical and decision-process related issues, such inaccuracy also originates from transport models’ inherent uncertainty, which in turns originates from the complexity of the systems generating both transport supply (e.g. services, infrastructure, and regulation) and demand. Uncertainty pertains to everything the modeller does not know to a full extent about the system object of the modelling process due to a limited knowledge or stochasticity of some model components. Thus, ultimately uncertainty reflects the inability of the modeller to represent the complex system in a deterministic way. By modelling complex systems, transport models are subject to uncertainty. The main consequence of such uncertainty is that point estimates of modelled traffic flows, and their derived measures, only represent one of the possible outputs generated by the model. Analyses based on point estimates invariably produce uncertain results and decisions taken relying on them may easily lead to unexpected consequences. Thus, it is essential to assess uncertainty inherent to transport models. This requires producing uncertainty measures by investigating which are the main sources of uncertainty within the model, how uncertainty propagates throughout the model and, finally, how it affects the model output. The purpose of the studies described in this thesis was to investigate uncertainty inherent to transport models. Despite its importance, the relation between the uncertainty of the transport model components and that of transport models output, and the processes that govern such relation, are not often explored by the existing literature. The collection of the four papers that compose the present thesis fills some of the gaps of this study area. The analyses were implemented by using an approach based on stochastic techniques (Monte Carlo simulation and Bootstrap re-sampling) or scenario analysis combined with model sensitivity tests. Two transport models are used as case studies: the Naestved model and the Danish National Transport Model. 3 The first paper investigated the effects of uncertainty in the volume-delay function parameters used in the Danish National Transport Model1. The results showed that some links in the modelled network have high sensitivity to the variability in the function parameters. In particular, the affected links mainly refer to short, mid-distance road types potentially hosting commuting traffic. Any assessment of projects potentially affecting traffic flow on those links should then take into consideration this sensitivity and integrate uncertainty analysis in the decision process. The second paper analysed the uncertainty in a four-stage transport model related to different variable distributions (to be used in a Monte Carlo simulation procedure), assignment procedures and levels of congestion, at both the link and the network level. The analysis used as case study the Naestved model, referring to the Danish town of Naestved2. The results highlighted that both the choice of the variable distributions and the use of different assignment algorithms has a noticeable impact on model output. Besides, it showed that the higher the link congestion, the lower the level of final uncertainty. The third paper presented in this thesis deals with uncertainty in transport demand forecasts. In particular, the uncertainty in the socio-economic variables (population, GDP, employment and petrol prices) growth rate projections is investigated and a method is suggested to assess its propagation throughout time. The analysis used as case study the Danish National Transport Model3. The resulting model output uncertainty was neither linear nor similar for the different model outputs investigated. Transport related projects may focus on different model outputs which have a different temporal uncertainty propagation patterns. Thus, making acknowledgeable the uncertainty propagation pattern over time specific for key model outputs becomes strategically important. 1 Manzo, S., Nielsen, O. A. & Prato, C. G. (2014). The Effects of uncertainty in speed-flow curve parameters on a large-scale model. Transportation Research Record, 1, 30-37. 2 Manzo, S., Nielsen, O. A. & Prato, C. G. (2015). How uncertainty in input and parameters influences transport model output: a four-stage model case-study. Transport Policy, 38, 64-72. 3 Manzo, S., Nielsen, O. A. & Prato, C. G. (2015). How uncertainty in socio-economic variables affects large-scale transport model forecasts. Forthcoming: European Journal of Transport and Infrastructure Research, 15-3, 64-72. 4 The last paper4 examined uncertainty in the spatial composition of residence and workplace locations in the Danish National Transport Model. Despite the evidence that spatial structure influences travel behaviour, there is no consensus on the strength of such influence. To provide insights to this topic, the study investigated a number of possible future scenarios affecting the spatial structure. Among the others, the observed trend of increasing population in the major Danish cities and the variation of employment location scenarios were analysed. The results show that the combined effect of higher urban density and social mobility produces an increase in number of trips; of these, density seems to be the dominant factor. However, at the same time, the proximity of the destinations increases, so decreasing the average trip length and consequently the total mileage travelled. Overall, results from the studies collected in this thesis visibly show the importance of integrating in a systematic way uncertainty analysis in transport modelling frameworks. This should be a standard approach to produce the information necessary to increase the quality of the decision process and to develop robust or adaptive plans. In fact, project evaluation processes that do not take into account model uncertainty produce not fully informative and potentially misleading results so increasing the risk inherent to the decision to be taken. Uncertainty analysis, by allowing identifying the main sources of uncertainty within the model and by providing knowledge on the level of confidence of the model output, ultimately enhances the robustness of the travel demand models and of the analyses based on their output.

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