Investigating uncertainty in BPR formula parameters: a case study

Investigating uncertainty in BPR formula parameters: a case study

Transport models play a prominent role in many decision-making processes. However, transport models are subject to uncertainty, which refers to the impossibility to model with a deterministic approach. If not properly quantified, the uncertainty inherent in transport models makes analyses based on their output highly unreliable. The main consequence of this inherent uncertainty is that modelled traffic flows cannot be expressed as a point estimate, because this would only represent one of the possible outputs generated by the model. Instead, modelled traffic flows are better expressed as a central estimate and an overall range of uncertainty margins articulated in terms of (output) values and likelihood of occurrence.

Uncertainty analysis relates to how uncertainty in each model component propagates to the model output and how to express the model output as a distribution, so reflecting the overall uncertainty within the model. The research described in this paper investigated uncertainty in the BPR formula parameters.

Within traffic assignment models, the relationship between travel time and traffic flows is commonly described by the BPR formula. The BPR formula works as a link performance function; given free flow travel time, observed flow and link capacity, it uses parameters to fit the equation to various types of roadways and circumstances. Usually, the values for the parameters are pre-defined, based on assumptions and practice. The present paper describes a work implemented to define the BPR formula parameters distributions from observed data. Two dataset related to the Danish road network, namely Mastra and Hastrid, were analysed so as to estimate the parameters distributions for three different types of roadways: highways, urban roads and local roads. Non-linear regression analyses were implemented to simultaneously calculate the values of the BPR formula parameters for each of the road sections included in the two samples, for a total of 28 sections. The resulting parameters distributions were then used to implement an uncertainty analysis on modelled traffic from the Danish national model based on Monte Carlo sampling technique combined with sensitivity tests. For comparative purposes, in some sections the parameters uncertainty was also quantified through Bootstrap random sampling simulation technique.

The results clearly highlight the importance for modelling purposes of taking into account BPR formula parameters uncertainty, expressed as distribution of values, rather than assumed point values. Indeed, the model output demonstrated a high sensitivity to different parameters values and type of distribution. This proved true for all the three types of roadways analysed, highways, urban roads and local roads. However, different levels of parameters uncertainty, i.e. different levels of spread around the mean values, were observed for the different roadway classes. The results also highlighted the differences in terms of parameters mean values and distribution shape resulting from the use of Monte Carlo sampling as compared to Bootstrap.

Bootstrap sampling procedures, whenever possible, should be preferred to Monte Carlo sampling due to the lower level of assumptions required by the modeller throughout the sampling process.