Prediction Model for Travel Time Variability for Copenhagen

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1. Introduction

Increasing traffic in the Copenhagen area escalates the level of congestion which leads to both higher average travel times and more unpredictable travel time (higher travel time variability). Even though travel time variability is recognised as a potentially significant contributor to the overall costs of travelling, there is no well-established practice to take it into account in project evaluations. Preliminary Danish calculations suggest that cost-benefit calculations underestimate travel cost by around 10-20% if travel time variability is not accounted for [4].

In order to include travel time variability in cost-benefit analyses, an important first step is to predict the level of variability in different traffic scenarios. This study is aimed to develop a prediction model that can predict the level of travel time variability as a function of daily traffic flow patterns. The prediction model is developed as an "add on" for the Danish national traffic model (NTM). The work relies on existing data provided by the Danish Road Directorate.

2. Background

There are three important issues that should be taken into account when modelling the relationship between travel times and traffic flow:

1. Spill back effects: Capacity problems and incidents causing bottlenecks with consequent congestion and queue-driving, affect travel times not just on the link in the network where they occur. Often the previous link is affected as well, potentially to a higher degree. Depending on the extent of the incident, the effect can spread backwards on several links.
2. Dynamic effects: Incidents causing congestion and queue-driving can have long-lasting effect on travel times, which only reduces slowly as the queue dissolves. This implies that observations of travel times and traffic flows are not independent across adjacent time intervals, but are related through a dynamic process.
3. Endogeneity: Traffic flow affects travel time because it can be necessary to reduce speed in dense traffic. Oppositely, travel time affects traffic flow, because congestion and queue-driving with low speed allows fewer cars to pass a given link per time unit.

If we fail to account for these issues, the estimated parameters could be biased, such that the estimated relations are systematically wrong. However, it is not easy to deal with these three issues.

Fosgerau & Small [5] have formulated a dynamic model which takes all three issues into account. They use an autoregressive model (which takes account of the dynamic effects), assuming that travel time on a given link in a given time interval depends on entry flow, queue length, downstream level of congestion (controls for spillback effects), vehicle composition, time and location specific effects such as weather conditions, and unobserved link characteristic. The endogeneity issue is handled by using regression with instrumental variables.

Our model is inspired by the approach in Fosgerau & Small [5], but uses a somewhat different approach.

3. Data

Various data sources for measurements of travel times and traffic flows were considered in the beginning of the work, including loop detector data, GPS data, Bluetooth data and camera data. Due to our specific requirements regarding congestion and data coverage, we ended up using data from the Køge Bugt Motorway, in the direction towards Copenhagen, which is very congested during mornings. The Danish Road Directorate provided measurements of travel times (a combination of loop detector and radar measurements, aggregated to a link level) from their Hastrid database and traffic counts (from loop detectors) from their Mastra database.

The first step is to merge data from the two databases. Since travel times are measured on link level and traffic counts are only available at point level, we choose to average the traffic flows from the measurement points within each link in order to aggregate flows to the link level. Using data of flow by vehicle type category, the flow in vehicle unit is converted into passenger car equivalents (pce). This information is not always available for the specific links we consider: where missing, we try to extrapolate the information from other links on the Køge Bugt Motorway in the same direction and time period, and if this is not possible, the observation is disregarded.

In order to minimize noise and attain the data quality needed, data filtering is done to the database, based on visual inspection of data. We use data with information about traffic incidents and road works to remove all observations related to periods with road works, in order to control the number of lanes on the links. Observations with speed below the reliable loop detector performance are also removed. In the analysis, we also have weather data available to help explain travel times.

4. Model approach and estimation

Our approach is to model the traffic pattern over an entire morning (5am-noon), in order to capture the dynamic effects that work over time. We assume that traffic has two states: congested and uncongested. For simplicity, we assume that traffic can switch from uncongested to congested and back again at most once during the morning. The prediction model consists of three models we refer to as the breakdown model, the recovery model and the travel time model.

The breakdown model predicts the transition from uncongested to congested conditions while the recovery model predicts the transition from congested to uncongested conditions. Both are formulated as duration models, i.e. the dependent variable is the duration until breakdown or the duration until recovery after breakdown occurs. We seek inspiration in a classic bottleneck model to provide the theoretical basis for the explanatory variables. We use traffic flow to explain traffic breakdown, as traffic flow in the uncongested state before breakdown can be considered exogenous. We use information about the overall morning demand to explain the recovery time. Finally, the travel time model is a simple model that predicts the means and variance of travel time depending on the state.

Data processing, analysis and parameter estimation uses the software packages STATA and Biogeme, applying maximum likelihood methods for parameter estimation.

5. Results and conclusions

The estimated breakdown and recovery models are tested using a simulation example and compared to the data as means of validation. Breakdown model validation is done by comparing the number of days without breakdown in simulation and data, as well as the predicted pattern of breakdown times. Simulation shows that the share of days with breakdown is slightly overestimated compared to real data. Even so, the simulation result shows that the model is able to reproduce the pattern of breakdown times rather well despite the simplicity of the model. The recovery model is validated by comparing the simulated and real patterns of peak durations. The model shows very close fit of average peak duration compared to the real data, though it predicts a much larger spread than the real data, implying a not very strong predictive power of the recovery model.

Considering the initial goal of the study is to construct a simple and applicable prediction model for travel time variability, the current prediction model seems to at least partly serve the purpose. However, the current version of the model does not handle spillback effects, which is a significant drawback. Therefore further modelling development is to be carried out. The next step is to include downstream density, queue length and weather variables as explanatory variables. It is hoped that spillback effects can be controlled for by introducing downstream density and queue length, such that these variables and the weather variables can help in explaining the observed peak duration pattern.

References

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