MEASURING AND VALUING TRAVEL TIME RELIABILITY – AN EXAMPLE FOR HARD SHOULDER OPERATION

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Most transport infrastructure investments aim to reduce average travel times and their appraisal depends to a large extent on travel time savings and their value. There is an increasing recognition that in addition to average travel times, their reliability affects travelers' choices and their valuation. However, the representation of travel time variability in network models, and hence our ability to forecast future impacts on reliability, has been limited. New data sources have enabled us to establish relationships between readily measurable characteristics and travel time variability. This now allows us to incorporate reliability in project appraisal, using standard economic cost-benefit techniques. The paper illustrates the method with an example of hard shoulder operations on Motorways around Birmingham in England.

Key words: economic appraisal, travel time variability, hard shoulder operation

1 Introduction

Travel time is an important driver for travelers' decision making. And as transport models generally produce information on average travel times, these are generally used to predict more subtle responses that consider all the component aspects of travel time, which are valued differently by travelers. For example, we know that wait times at bus stops and transfer times between modes have higher weights associated with them (are disliked more) than in-vehicle time. Fortunately, these weights do not affect the linear additivity between link times, and most network models can deal with this naturally and efficiently.

We also know that travel time reliability is valued by the traveler. Incorporating this, however, poses substantial challenges to the modeler:

- The definition of reliability is not straightforward;
- Even if defined, the measurement of reliability is expected to be data hungry;
- The definition of reliability must be supported by standard inputs to and outputs from network models;
- The measure of reliability must be accompanied by an appropriate weight, representing the value that travelers place on this, compared with average travel times.

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2 Defining reliability

Although others have suggested and used alternative definitions, e.g. [5], reliability (or rather the lack of it) is expressed conveniently as travel time variability.

Travel time variability is the random, day-to-day variation of the travel time that arises in congested situations even if no special events (such as accidents) occur. It should not be confused with within-day variations (eg between the peak and off-peak periods). The latter can be predicted by travelers; the former cannot. There are several ways to quantify travel time variability. Commonly used is the standard deviation of travel time; this can be estimated at link level but more convenient for application in network models is a route level analysis.

Modern datasets, particularly those collected routinely using loops (for example at traffic signals or on Motorways) or using GPS tracker systems, provide large amounts of data that allow us to estimate the standard deviation of travel time, by vehicle type, by time period and by area type. Several studies have estimated such relationships as a function of network characteristics – critical is to bear in mind that for forecasting purposes the variables must be generated by the transport model.

2.1 Relationships to express variability

For urban areas, and for route-based analysis a convenient and well-fitting functional form is:

$$CV = \alpha CI^{\beta} d^{\gamma} \tag{1}$$

where: CV is the Coefficient of Variation, the ratio of the standard deviation of journey time to the mean journey time;

CI is the Congestion Index, the ratio of the congested travel time in the period considered to the minimum possible time;

d is the length of the route.

The standard deviation of journey times is calculated from a large number of day to day observations. The relationship is intuitive (the variability is a function of ‘excess’ travel time experienced), and it is simple (with only two variables and three parameters). And the explanatory variables, CI and d, are easy to produce outputs from network models.

In published work [1], other explanatory variables have been tested, but none of these contributed much in terms of explanatory power:

- number of lanes
- number of intersections
- speed limit
- length
- volume-delay function
- “type” of road (an indicator of its size and importance)

For Motorway links, which are generally longer, where there is less junction interaction, and where route based analysis is less meaningful, link-based relationships have been estimated [6] of the form:

$$sd = \alpha + \beta M + \gamma M^{2} + \delta M^{3} \tag{2}$$

where sd is expressed in sec/km and M is the mean journey time per kilometer.

Whereas the route based analysis for urban areas ignores the road type used, for the Motorway analyses different relationships have been estimated for different link types, linked to number of lanes and operational regime.

3 Measuring travel time variability

We have used two datasets used to measure travel time variability, and to estimate relationships for forecasting:

- HATRIS, the UK Highways Agency's Traffic Information System, for the link-based Motorway relationships;
- SPECTRUM, the database of traffic data maintained by the Birmingham conurbation authorities, which includes daily journey time estimates from CJAMS analyses of GPS Tracker data [4].

In both cases a large number of data points were used to measure observed travel time variability and estimate the parameters for the functional relationships in equations (1) and (2).

3.1 Urban variability

For the urban network relationship, 19 routes were identified (see figure1).

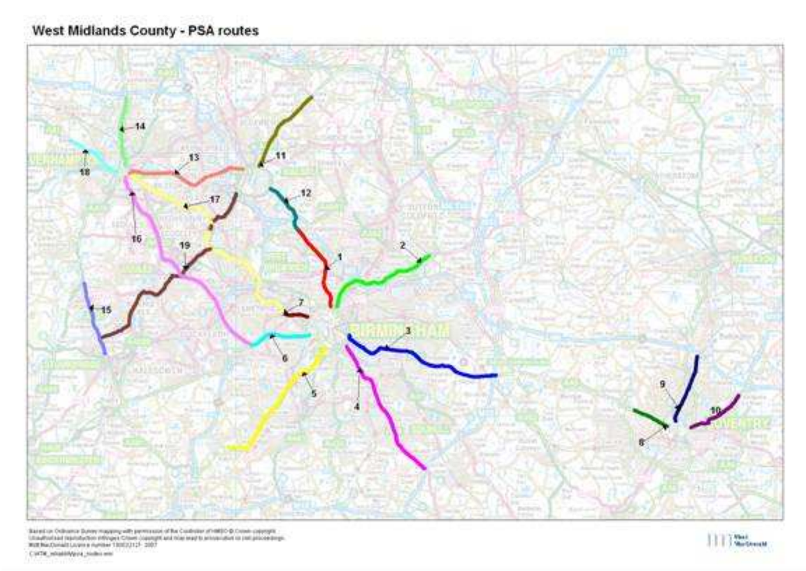

Fig. 1 Routes used to estimate the urban travel time variability relationship

For these routes, average peak period journey time observations were obtained for, typically, 50-150 days in 2007, for the AM and PM peak periods separately, giving 100-300 observations for each route. On the basis of the free flow travel time (assumed to be equal to that measured in the off-peak period), the observed travel times in the peak periods, and the route lengths, local parameters for function (1) were estimated as follows:

$$CV = 0.15CI^{1.41}d^{-0.33} \tag{3}$$

All coefficients are significant at the 95% level, and the R-squared statistic is 0.706. We can compare this local relationship with the default advised by the Department for Transport [2] estimated from different data and using a slightly different technique of analyzing GPS data:

$$CV = 0.16 CI^{1.02} d^{-0.39} \quad (4)$$

Both equations are similar, giving confidence in the estimation and ultimate application.

3.2 Motorway variability

Motorway link variability (rather than route variability) was calculated from more than 23,000 data points on different link types. More detail can be found in [6], but for our application two relationships were most relevant: dual 3-lane motorways (D3M) and dual 3-lane motorways with hard shoulder operation (D3M HS). There were 17,000 data points available for the standard 3 lane motorways, and nearly 2,000 for motorway links with hard shoulder operation. :

$$sd_{D3M} = -58.68 + 2.20M - 1.45\times10^{-2} M^2 + 3.64\times10^{-5} M^3 \quad (5)$$

$$sd_{D3MHS} = -89.07 + 5.93M - 1.34\times10^{-2} M^2 + 1.10\times10^{-5} M^3 \quad (6)$$

4 Hard shoulder operation

Hard shoulder running is one of the most visible aspects of Active Traffic Management (ATM); in periods of high demand and when congestion is expected to occur, the hard shoulder is also used as a running lane; see figure 2. When demand is less, the hard shoulder fulfils its standard function. This enables capacity to be released when needed, without building additional lanes on the Motorways.

Now used in, for example, The Netherlands, Germany and France, the first pilot scheme in the UK, on the Motorways around Birmingham, opened in 2006 and has been extensively monitored [3].

Fig. 2 Hard shoulder operation on Motorway near Birmingham

The monitoring exercise for the M42 around Birmingham established that:

- Capacity increased by 7%; spare capacity still exists;
- Average travel times along the stretch where hard shoulder operates increased, by about 9% (partly due to additional demand);

- Travel times during periods of recurrent congestion (such as the PM peak) reduced by between 9 and 24%;
- Variability in travel times fell by 22%.

The success of the ATM trial of hard shoulder running has been such that the Highways Agency, responsible for the management of the Strategic Road Network in England, is extending the area of operation to a larger part of the Motorway network around Birmingham. How much in travel time variability benefits would this generate?

5 Application in appraisal of hard shoulder operation

To assess the reliability benefits of hard shoulder operation on a larger part of the Birmingham Motorway network, we calculated four things:

- The 'first-order' benefits on the Motorway itself, using a link-based assessment and equations (5) and (6);
- The 'second order' benefits on the rest of the urban network, using equation (3)
- The value of time for travelers on the network
- The relative value of reliability, which is a value for a minute of standard deviation equal to 0.8 times the value of a minute of travel time (the raliability ratio)

As far as possible we used standard values advised by the Department for Transport in their WebTAG guidance, particularly Unit 3.5.6.

For OD-based analyses on the urban road network(second-order effects) purpose-specific values of time are used. Table 1 shows these.

Tab. 1 Values of time used (Source: WebTAG)

Trip Purpose	**Value of Time (£/hr/veh)**
Car Business	£30.18
Car Commute	£5.74
Car Other / Education	£7.90
Light Goods Vehicle	£11.55
Heavy Goods Vehicle	£10.18

For the link-based Motorway analyses trip purpose is not known, so an averaged value of time of £11.28 per hour per vehicle has been used. Benefits are calculated using the rule of a half.

First order reliability benefits on the Motorway sections where hard shoulder operation was to be implemented amounted to just under 3 pence per veh.km.

The second order effects in the wider urban network are calculated at an OD basis, using equation (3). There are two practical refinements required:

- The congestion index (CI) is constrained to values less than 2; in model applications higher values can occur that are unrealistic in real-life;
- As the Motorway elements of trips are excluded (they form part of the first-order effects), the study area is subdivided into four zones, cordoned at Motorway entry and exit slip roads; see

figure 3. Hence, some longer distance single trips are split into two; there will be an inevitable but currently unknown effect on variability calculations for these.

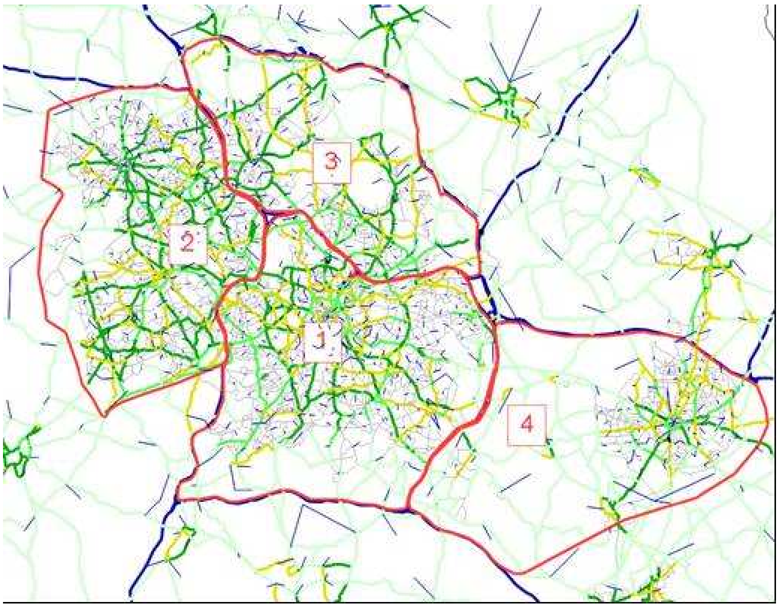

Fig. 3 Zoning of study area to enable second order effects to be calculated

The calculated second order effects (expressed as benefits per veh.km.) are about 0.2 pence, less than 10% of the first order effects.

6 Conclusions

The paper presents an analysis of reliability benefits of hard shoulder operations on Motorways. A general method for estimating travel time variability (for Motorway links and wider urban areas separately) is presented that can be estimated locally and applied in the Czech Republic also, dependent on data availability. Substantial reliability benefits are determined; calculations in [2] show that, dependent on location and type of infrastructure investment, these can be between 10 and 25% of traditional travel time benefits.

Reference literature

1. ELIASSON, J. Forecasting travel time variability. European Transport Conference, Strasbourg, 2006, and available on www.etcproceedings.org.
2. GILLIAM, C, CHIN, TK, BLACK, I and FEARON, J. Forecasting and appraising travel time variability in urban areas. European Transport Conference, Noordwijkerhout, 2008, and available on www.etcproceedings.org.
3. HIGHWAYS AGENCY. ATM monitoring and evaluation; 4-lane variable mandatory speed limits; 12 month report. Mott MacDonald Report 203754_MM_007_V3, DOC/1807/V3, 2008.
4. HOLTOM, R and STOREY, B. The use of historic GPS data in transport and traffic monitoring. Traffic Engineering and Control, 2003, pp 376-379.

5. KOUWENHOVEN, M, VAN GROL, R, KROES, E and SCHOEMAKERS, A. Development of a tool to assess the reliability of Dutch road networks. European Transport Conference, Strasbourg, 2005, and available on www.etcproceedings.org.
6. SIRIVADIDURAGE, S, GORDON, A, WHITE, C and WATLING, D. Forecasting day to day variability in travel times on the UK Motorway network. European Transport Conference, Noordwijkerhout, 2009, and available on www.etcproceedings.org.