



Benefit estimation with discrete choice models

March 2013

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Issue and revision record

Revision	Date	Originator	Checker	Approver	Description	Standard
A	Dec 2012	A Gordon	J Baker	J Baker	First issue	
B	Jan 2013	A Gordon/R Batley	J Baker	J Baker	Second issue	
C	Feb 2013	A Gordon	J Baker	J Baker	Third issue	
D	March 2013				Fourth issue	

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1. Introduction

Recent work carried out by Mott MacDonald and the University of Leeds (Mott MacDonald 2013a) has sought to monetise the social benefits associated with the provision of bus services. The basic principle is that the social impact of the provision of bus services comes from enabling certain trips to take place that otherwise would not have done. While existing WebTAG guidance captures the economic and environment impact of bus use, it does not explicitly identify monetised values for the social impact.

We equate the social impact with the value that travellers place on the activity that they undertake at the destination of their trip. The social benefit is therefore expressed in terms of a monetary value per return bus trip. In terms of the impact of bus services, the benefit only accrues to those who would not make the trip at all in the absence of bus¹. Bus travellers who would use a different mode in the absence of bus would still participate in the activity and receive the associated benefit. For this latter group the provision of bus services is primarily an economic benefit in that it affects their travel time and/or their out of pocket expenses (public transport fares or car-related costs), and is therefore captured elsewhere in a WebTAG appraisal.

WebTAG requires that user benefits are calculated using the rule of a half (ROH), as described in [TAG Unit 3.5.3 Transport User Benefit Calculation](#)²³. Using the WebTAG formulation of the rule of a half means that no additional benefits can be calculated using the social value per return trip – they are already captured in the ROH calculation⁴. Part of the reason for this is that the WebTAG version of ROH is best suited to continuous demand models and is less appropriate for discrete choice models.

However, ROH can be formulated in a way that is better suited to discrete choice models. Using this formula, it is possible to take account of the social value per trip in benefit estimation. The purpose of this note is to explain this variation of the ROH.

For this version of the ROH to be applicable the demand model must fulfil the following requirements:

- It must be a discrete choice model, rather than a continuous demand model.
- The model must explicitly model mode choice **and** the choice between travelling and not travelling. The modelling of other choices such as destination and time period is optional.

The note assumes that the reader is familiar with the use and application of discrete choice models and understands the terminology.

Section 2 sets out the method and Section 3 presents a brief example.

¹ Which may mean that bus is physically not available, or has a generalised cost of travel (i.e. a combination of fare, access/egress time, waiting time and in-vehicle time) that is so high that it is not used.

² <http://www.dft.gov.uk/webtag/documents/expert/unit3.5.3.php>

³ There are some exceptions to this, specifically benefits that are not perceived directly by the user, such as non-fuel car operating costs for non-business travellers.

⁴ Although it is possible to use the social value per trip to split the WebTAG ROH benefits between economic and social impacts; see Mott MacDonald (2013b).

2. The method

2.1 Discrete choice formulation of the rule of a half

The discrete choice formulation of the rule of a half (ROH) can be written⁵:

$$\text{Benefit relating to alternative } k = \frac{1}{2}(\pi_k^0 \cdot GC_k^0 - \pi_k^1 \cdot GC_k^1) \cdot (T^0 + T^1) \quad (1)$$

where

superscripts 0 and 1 indicate the before (do-minimum) and the after (do-something) scenarios respectively

GC_k is the generalised cost of alternative k

T is the total number of trips

π_k is the probability of travellers choosing alternative k (obtained from a discrete choice model)

The precise interpretation of T depends on the choices being modelled. For example, if only mode choice is modelled then T would be the total number of trips (all modes) between a given zone pair. If mode and destination choice are modelled then T would be the total number of trips (all modes) from a given origin zone.

For comparison, the WebTAG/continuous demand formulation of ROH is given by:

$$\text{Benefit relating to alternative } k = \frac{1}{2}(GC_k^0 - GC_k^1) \cdot (T_k^0 + T_k^1) \quad (2)$$

where

T_k is the number of trips using alternative k

The main difference between the two is that the discrete choice version uses **expected** generalised costs, through the inclusion of the π_k terms. Note also that the discrete choice version uses the total trips; the continuous demand version uses the trips using alternative k (which is equal to $T \cdot \pi_k$).

The discrete choice formulation is completely general and can be used wherever a discrete choice model is used to predict travel demand.

However, to be able to include the social impacts of travel, the choice model must include the option not to travel, i.e. the “not go” alternative must be one of the alternatives k . This will often be the case when trip

⁵ This version of the ROH is adapted from Batley (2012). See Appendix D of Mott MacDonald (2012d), which shows this to be equivalent to calculating the Hicksian Compensating Variation.

frequency is modelled as a discrete choice of how many trips to make (which will include the option of zero trips, i.e. “not go”).

In general, the alternatives k need to include all of the choices included in the choice model. In addition to the “not go” option, this may include (but is not limited to) the choice of mode, destination and time period.

2.2 Definition of generalised cost

For consistency with WebTAG principles the generalised cost GC should be calculated, in money units, using the values of time and vehicle operating set out in [TAG Unit 3.5.6: Values of Time and Operating Costs](#). Any weightings applied to components of travel time such as walking, cycling and waiting, should be consistent with that guidance.

The exception to this is the cost of the “not go” alternative. The following costs should be used for the “not go” alternative, depending on whether the traveller has a concessionary travel pass for bus travel:

Table 2.1: Cost of a “not go” choice (2010 values and prices)

Concessionary fare status	
Holds a concessionary travel pass	£3.84
Does not hold a concessionary travel pass	£8.17

Source: Mott MacDonald (2012c)

Note that these are values per return trip equivalent. If the costs for the travel alternatives are based on two-way costs then the above values can be used. If the costs for the travel alternatives are based on one-way costs then the above values should be halved.

Decomposition of cost components

The benefit formula (2) is expressed in terms of the generalised cost GC . However, it can be broken down as the sum of the contributions of individual cost components:

$$\begin{aligned}
 \text{Benefit relating to alternative } k &= \frac{1}{2}(\pi_k^0 \cdot GC_k^0 - \pi_k^1 \cdot GC_k^1) \cdot (T^0 + T^1) \\
 &= \frac{1}{2}(\pi_k^0 \cdot M_k^0 - \pi_k^1 \cdot M_k^1) \cdot (T^0 + T^1) \\
 &\quad + \frac{1}{2}(\pi_k^0 \cdot J_k^0 - \pi_k^1 \cdot J_k^1) \cdot (T^0 + T^1) \\
 &\quad + \frac{1}{2}(\pi_k^0 \cdot S_k^0 - \pi_k^1 \cdot S_k^1) \cdot (T^0 + T^1)
 \end{aligned} \tag{3}$$

where

M is the out of pocket monetary expenses (fares, tolls, parking charges, vehicle operating costs)

J is the time cost

S is the “social cost” (as set out in Table 2.1 for “not go”, zero for other alternatives)

and

$$GC = M + J + S$$

2.3 Segmentation

As with the WebTAG ROH formula, equation (1) can be applied separately to different segments in the model, for example by trip purpose, income or car availability.

2.4 Additional processing

Benefits calculated using the discrete choice version of the ROH will need subsequent adjustment, identical to when the WebTAG ROH has been used:

- Annualisation of benefits to represent a full calendar year
- Interpolation of benefits between modelled years, and extrapolation from the last modelled year to the end of the appraisal period
- Application of real changes in value of time and vehicle operating costs⁶
- Discounting

These are standard steps in a WebTAG appraisal and are not discussed further here.

⁶ The values set out in Table 2.1 should be assumed to increase in real terms as the same rate as non-working values of time, as set out in Table 3b of TAG Unit 3.5.6.

3. Worked example

Suppose we have a discrete choice model that considers three alternatives for a particular trip: bus, car (driver) and “not go”. Also suppose that we are looking at a particular origin-destination pair, for a demand segment that represents travellers who do not hold a concessionary travel pass.

In the do-something scenario bus fares are increased, which encourages a switch from bus to the car and “not go” alternatives.

This is shown in Table 3.1 which includes the generalised cost, the probability of choosing each alternative (estimated from a discrete choice model), and the resulting expected cost, for the do-minimum and do-something scenarios.

Table 3.1: Worked example: costs and probabilities⁷

Alternative	Do minimum			Do something		
	Cost (£) GC_k^0	Probability π_k^0	Expected cost (£) $GC_k^0 \cdot \pi_k^0$	Cost (£) GC_k^1	Probability π_k^1	Expected cost (£) $GC_k^1 \cdot \pi_k^1$
Not go	8.17	0.18	1.48	8.17	0.22	1.76
Bus	6.00	0.35	2.09	8.00	0.23	1.81
Car	5.00	0.47	2.35	5.00	0.56	2.79

If we also assume that $T^0 = T^1 = 1000$ then applying equation (1) gives the following benefits by alternative; benefits calculated using the WebTAG ROH are also shown:

Table 3.2: Worked example: benefits (2010 values and prices, not discounted)

Alternative	Benefits (£)	
	Discrete choice ROH	WebTAG ROH
Not go	-277	0
Bus	275	-575
Car	-438	0
Total	-439	-575

Note that the discrete choice ROH results in benefits for all alternatives. The WebTAG ROH (equation (2)) only gives impacts for bus, as this is the only alternative where the generalised cost changed. That is a result of the WebTAG convention of the attribution of benefits by source – the impacts arise from a change in bus costs, so all impacts are reported as bus-related. As noted earlier, this is not always a helpful way of presenting the impacts.

The two methods give total benefits that are roughly the same order of magnitude. They are not identical, nor would we expect them to be. The WebTAG ROH implicitly assumes the demand response is due to a (path independent) income effect (regardless of the actual demand model used to provide the forecasts).

⁷ Figures in the table have been rounded to two decimal places. Readers may therefore not be able to reproduce exactly all the calculated values.

The discrete choice ROH assumes the demand response is due to substitution effects, which is more in keeping with the logit model form used in this example.

In reality the demand response is likely to be a combination of income and substitution effects. Both forms of the ROH therefore represent an approximation. Which one is more accurate will depend on the relative importance of the two effects.

4. References

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