Economic Assessment with Microsimulation Models

Authors :

Pete Sykes, Iain Clement, SIAS Limited

Introduction

The requirement for a traffic and economic assessment, or 'cost-benefit analysis', results from a need for government at all levels to secure 'value for money' from any investment expenditure. In the transport sector, cost-benefit assessments provide a consistent methodology to compare the 'value for money' of an individual scheme to other schemes within a roads programme.

The UK Treasury definition of 'cost benefit analysis' is:

> *'Analysis which quantifies in monetary terms as many of the costs and benefits of a proposal as feasible, including items for which the market does not provide a satisfactory measure of economic value.' [Ref: Appraisal and Evaluation in Central Government, HMT, 2003].*

The Design Manual for Roads and Bridges states:

> *Cost-benefit analysis is designed to measure the net social benefit of a scheme by comparing the benefits generated to the sum of the costs incurred. If benefits exceed costs, implementing the road improvement would be advantageous for society overall; conversely, if the benefits amount to less than the costs society would remain better off by not undertaking the improvement. [Ref: DMRB Vol 15 Sec 1 Part 3].*

Microsimulation provides a new approach to the understanding, representation and analysis of road traffic. 'Conventional' traffic modelling systems assign traffic flows to roads and then infer speeds, delays and routeing, while microsimulation systems model individual vehicles for the duration of their entire trip, thereby providing detailed traffic flow and related statistical information.

Program for the Economic Assessment of Road Schemes – PEARS

The methodology and key parameters for undertaking a traffic and economic assessment are outlined in the DfT's Transport Analysis Guidance (WebTAG) which includes advice on appraisal period, discount rates, present value year and so on. WebTAG also contains more detailed information on "Values of Time" for different classifications of vehicles, drivers and passengers, and guidance on how these should be interpreted. The PEARS output is a WebTAG compatible table of costs discounted to a present value year (currently 2002), with economic performance summarised in the form of Net Present Value (NPV), Benefit to Cost Ratio (BCR) and First Year Rate of Return (FYRR). Implicit in the comparison of these costs is the simple "Yes or No" answer to the value for money question.

PEARS undertakes trip-based assessments of changes in travel time costs and vehicle operating costs. Traditional link-based assessments (e.g. NESA, COBA) and matrix-based assessments (e.g. TUBA) rely on a single travel time and vehicle operating cost for each link or origin/destination movement representative of the whole modelled period. PEARS, which derives its input data from microsimulation, has access to the costs of each individually modelled vehicle on the network and aggregates these to derive the overall cost.

The key difference between microsimulation and PEARS and traditional assessment methods lies in the source of the trip costs data. Microsimulation is able to capture very small changes in travel time and fuel use. In comparison, traditional traffic models do not have access to this level of detail and hence cannot produce results which take into account some important contributors to the cost equation.

Two examples of how this difference can be important are described here.

Overtaking Behaviour & Platoon Dispersion

On a single carriageway, vehicles may be slowed into a platoon behind a single lead vehicle, typically a heavy goods or agricultural vehicle. To overcome this, a carriageway widening road improvement scheme might be devised to benefit the vehicles that can now overtake, and hence disperse the platoon. It is important to note that the benefit is not felt just over the length of the scheme but for some distance downstream. Microsimulation can capture the detailed effect, and PEARS can translate this into a monetary value for inclusion in the overall cost benefit analysis.

S-Paramics includes an overtaking model in which a vehicle will first assess its desire to overtake based on its target link speed and the achieved speed of the vehicle ahead. It will then assess its ability to overtake, based on the gap available ahead of the vehicle to be overtaken and the visibility of the road ahead coupled with the presence of an oncoming vehicle in that space. The manoeuvre will be initiated when both the desire to overtake and the available gap are present.

A recent commission for the Scottish Executive, on behalf of all UK government transportation departments, was designed to assist with the preparation of a new technical advice note for wide single 2+1 overtaking lanes looked at a number of parameters, including:

- economic scheme length
- extent of downstream benefit
- platoon lengths

In all cases, the benefits were compared to a reference base of either standard S2 (7.3m) or Wide Single WS2 (10.0m) carriageway. Wide Single WS2+1 carriageways comprise the development of a third traffic lane to provide dedicated overtaking. Traffic in the opposing direction is prohibited from overtaking.

Further benefits can be accrued through provision of alternating overtaking lanes arranged in either conflicting or non-conflicting configurations. In conflicting, or critical, configurations, the direction of alternate overtaking is towards the mid point of the scheme (nose to nose). In non-conflicting, or non-critical, configurations, the direction of alternate overtaking is towards the ends of the scheme (tail to tail). The differences to the driver lie in the changes in platooning levels, and hence gaps, in the oncoming traffic as the overtaking manoeuvre is to be attempted

An S-Paramics microsimulation model was developed to replicate a 15km section of single carriageway. The model was coded to include an approach length and a central study section followed by a run-out section. The 4.5km approach alternately allowed and barred overtaking, to ensure that realistic platoons would form at the start of the study section, which varied in length according to the each test. A 10km run-out section enabled the downstream benefits to be measured.

The model was calibrated by adjusting the overtaking parameter so that the vehicle order change in the model matched that from a set of number plate matching surveys. In all models, the HGV proportion was fixed at 10% and both conflicting and non-conflicting overtaking lane arrangements were evaluated.

For each test scenario, an equivalent Do-Minimum scenario was also developed, against which the scheme was assessed. Both were modelled for opening year and design years, although it should be noted that PEARS can deal with multiple assessment years. Each Do-Minimum and Do-Something scenario was simulated 10 times using a random seed value to ensure a distribution of results. The assessment was then repeated for three or four different flow ranges.

The first assessment looked at economic justification for various scheme lengths. The test model assumed that the road would be upgraded from either a standard 7.3m S2 single carriageway or 10.0m WS2 wide single carriageway to 12.5m WS2+1 carriageway. In all models, the HGV proportion was fixed at 10% with the flow range varied between 5,000 and 15,000AADT.

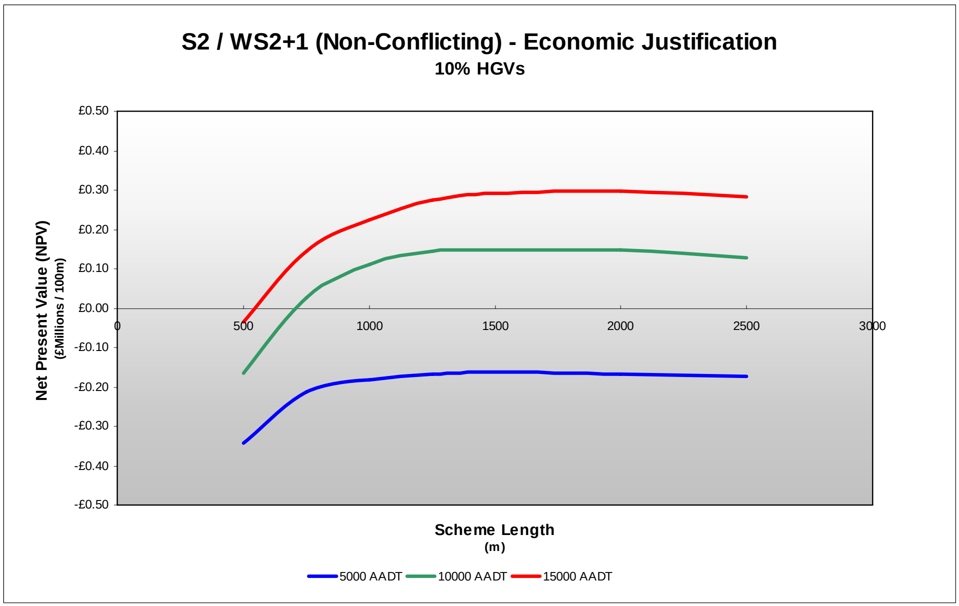

Figure 3 : S2 to WS2 Economic analysis

The results of the S2 to WS2+1 assessment are summarised in Figure 3. They indicated that:

- S2 to WS2+1 would be difficult to justify economically in low flow situations (<5,000AADT)
- WS2 to WS2+1 would be easier to justify economically because of its lower scheme cost
- the optimum overtaking section length lies between 750m and 1,250m (1,000m)
- beyond 1,250m, there is little return for additional cost

The second of the assessments looked at the impact of downstream benefits on vehicle speeds. The test models again assumed that the road would be upgraded from either a standard 7.3m S2 single carriageway or 10.0m WS2 wide single carriageway to 12.5m WS2+1 carriageway. Again, in all models, the HGV proportion was fixed at 10%.

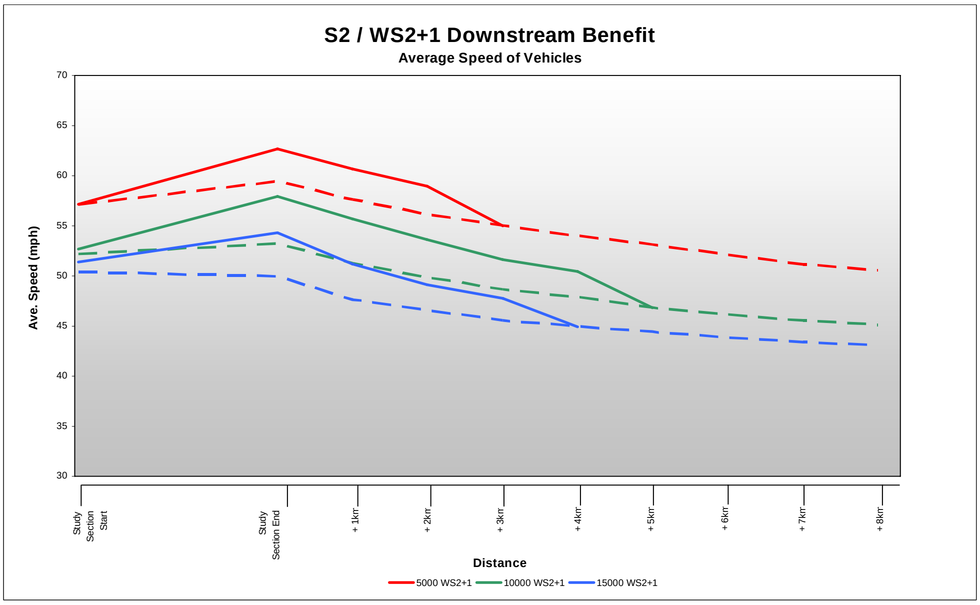

Figure 4 : S2 to WS2 Downstream Benefit

The results of the S2 to WS2+1 assessment are summarised in Figure 4. They indicated that:

- at 10,000 AADT, the benefit in increased vehicle speed is accrued for around +5km downstream
- at 5,000 AADT, lower initial differential between base and design speeds indicate that overtaking demand is satisfied earlier
- at 15,000 AADT, benefit is again of short duration as overtaking vehicles soon catch up on next platoon

Note: All tests assume no overtaking occurs downstream and that benefits will be of longer duration if overtaking opportunities exist downstream. Combined with some of the other parameters being tested, the analysis suggests that 2+1 overtaking lanes should be located every 5 to 8km to allow optimum economic performance.

The last of the assessments looked at the impact of platoon dispersion. Again, these key traffic characteristics can only be captured using microsimulation techniques. The test models assumed that the road would be upgraded from either a standard 7.3m S2 single carriageway or 10.0m WS2 wide single carriageway to 12.5m WS2+1 carriageway. As before, in all models the HGV proportion was fixed at 10%. The results of the S2 to WS2+1 assessment are summarised below in Figure 5.

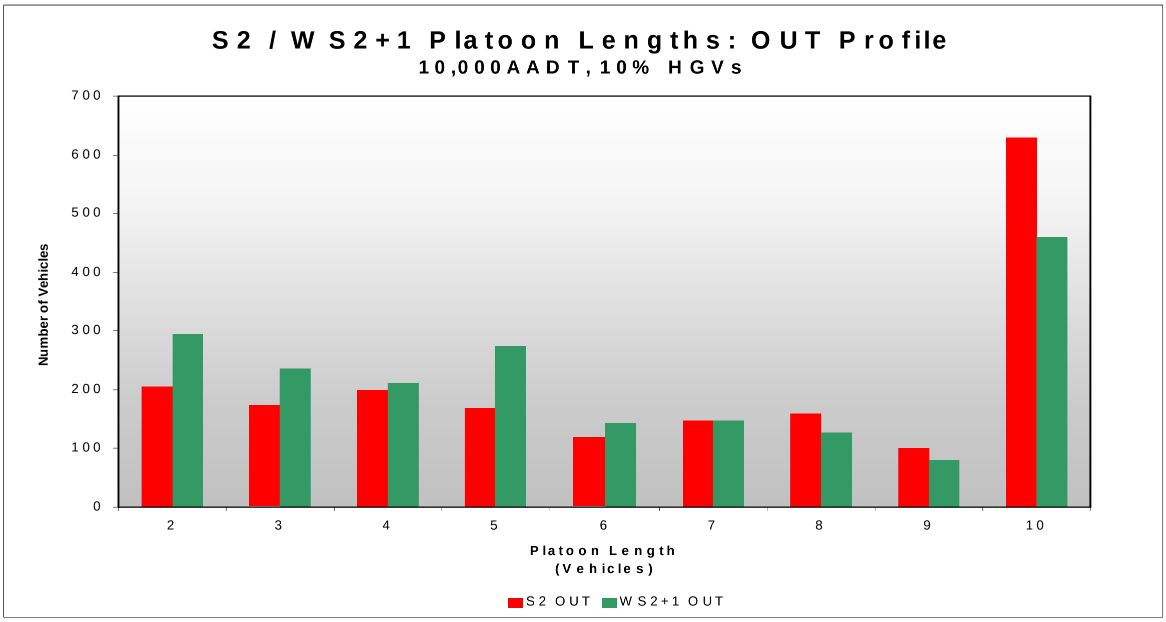

Figure 5 : S2 to WS2 Platoon Lengths

The analysis of the platoon profile exiting the study section clearly indicted a reduction in the number of longer platoons in favour of shorter platoons of 4 to 5 vehicles. The assessment concluded that:

- number of vehicles in platoons >5 reduces from 60% to 48% of the total number of vehicles
- number of vehicles in platoons >10 reduces from 33% to 23% of the total number of vehicles

By evaluating the economic benefits in detail using a microsimulation model it is possible to capture very small changes in travel time and vehicle operating costs which would otherwise be lost. A cost benefit package such as PEARS enables these savings to be translated into monetary benefits and the overall cost benefit analysis of a proposed road improvement scheme can be more accurately undertaken. It should be noted that the main benefit is felt not in the area where the work is undertaken, but for many kilometres downstream. Simply modelling the immediate area where the work is to be done will not capture the true effects of the work, and modelling the wider area with macro level assignment techniques cannot capture the detailed and significant effect of platoon formation and dispersion.

Fuel Consumption

Network options are evaluated on a combination of social costs and vehicle operating costs. The latter includes fuel consumption and hence the modelling system is required to derive these costs from its simulation of the network.

Traditional macroscopic road traffic modelling systems use speed/flow graphs to predict the achieved speed on a link under different flow rates. In congested situations these will correctly show that average speed is slower than in free flow conditions. However they will average the speed and flow and apply these averages to all vehicles on the entire link rather than use the instantaneous speed and acceleration of each individual. A lower constant average speed generally equates to lower fuel consumption, but in a real congested network this situation does not exist, and the average may actually represent a range of stop start conditions where fuel consumption increases.

Let us consider an example of a dual carriageway with a signalised roundabout interrupting traffic flow. Vehicles travelling along this road will have a reduced average journey speed due to the need to join the approach queue and negotiate the roundabout. A proposal is made to grade separate the roundabout and the economic evaluation includes vehicle operating costs. Let us hypothesise that the overall journey speed rises from 50mph to 70mph for the segment of dual carriageway.

An assessment using overall journey times will assign a higher fuel consumption figure to the design scheme using the grade separated roundabout as the Department for Transport’s WebTAG advice considers the optimum fuel efficient speed for an average car to be around 55mph. An assessment based on a microsimulation model will take into account the difference between a cruise over the junction at 70mph and an interrupted journey through it, involving decelerations, queueing and accelerations. Intuitively we all understand that the interrupted journey incurs greater fuel use.

This is backed up by a brief experiment in which a traffic calming speed limitation (5mph) was placed on a short section of urban road in a traffic model. This, as expected, slowed traffic and contributed to an overall increase in travel time. Comparisons of fuel use costs over the evaluation period were made and are summarised in Table 1 below. Note that while the fuel cost figures are not identical in the two methodologies they are quite similar. The critical measurement is the difference in the figures between smooth flow and start/stop driving. Using the journey time methodology as recommended by the WebTAG guidelines an overall increase in fuel costs of 3.42% was measured. This is to be expected as journey time has increased and vehicles are not operating at their most efficient speed. Using S-Paramics microsimulation, the speed and acceleration of each vehicle is linked by engine type to a fuel use map and the fuel consumption for the journey is aggregated at each simulation time step. In this case the overall increase in fuel cost was estimated at 8.58%, which reflects the increased consumption in the acceleration phase downstream of the traffic calming.

Table 1 Base Fuel costs

	Smooth	Stop Start	Increase
WebTAG	£16,885,470	£17,462,990	3.42%
Microsimulation	£15,705,350	£17,052,260	8.58%

Fig 6 shows graphically where fuel is used in terms of a 3D surface overlay above a road layout in a microsimulation model. This confirms that fuel use is higher in the road section where vehicles are accelerating out of the queue as the signals change at the junction.

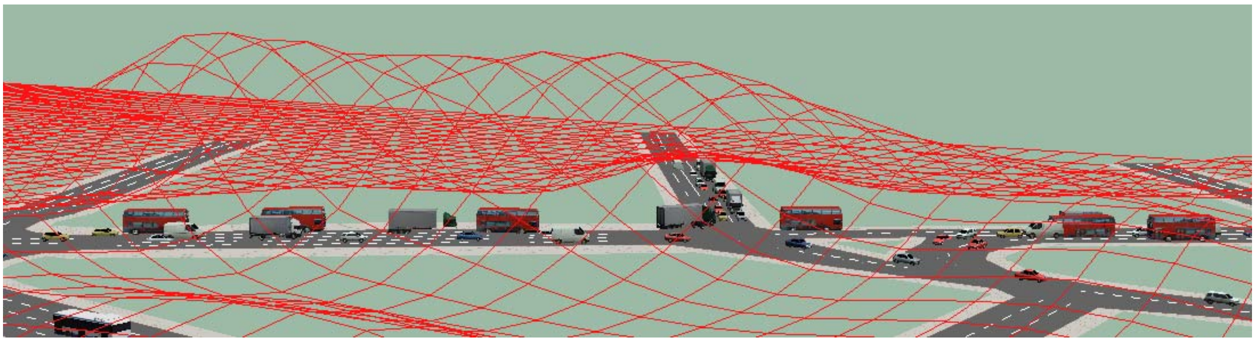

Figure 6 : Fuel use

In summary, vehicle fuel use is higher in stop start driving conditions, and a microsimulation model should be used to deduce fuel consumption from the detail of each vehicle's speed and acceleration profile for factoring into the overall economic assessment of road schemes.

Conclusion

By evaluating the economic benefits in detail using a microsimulation model it is possible to capture very small changes in travel time and vehicle operating costs which would otherwise remain hidden. A cost/benefit analysis package such as PEARS can be used to unlock the resulting potential monetary benefits and enable the economic evaluation of a proposed road improvement scheme to more accurately reflect its operation.