How microsimulation unlocks the economic benefits of road improvement schemes

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INTRODUCTION

UK Highway improvement schemes must pass the value for money test prescribed by official guidance in the Department for Transport's Design Manual for Roads and Bridges and Transport Analysis Guidance WebTAG, which incorporates the new thinking of the past decade resulting from a better understanding of variable demand and multi-modal issues. Despite this, contemporary cost/benefit appraisal systems fail to realise the full economic potential of some schemes where the devil is in the detail, often producing counter-intuitive results.

In providing a new approach to the understanding, representation and analysis of road traffic flow, microsimulation also enables us to unlock the benefits of highway improvement schemes which have hitherto proved elusive. Because microsimulation systems model individual vehicles for the duration of their entire trip, they provide detailed traffic flow and related statistical information which can be analysed in a manner which reflects the experience of real road users. For instance, if we grade separate a congested roundabout we should not expect the vehicle operating costs to go up because of the higher average speeds resulting from the reduced congestion, yet this is what can sometimes happen if we blindly apply the procedures. Common sense tells us that stop-start queueing is more fuel inefficient and polluting than smooth running. Now microsimulation provides us with the means to accurately assess the performance and behaviour of individual vehicles and their drivers, and enables us to measure the economic benefits consistent with official guidelines.

PROGRAM FOR THE ECONOMIC ASSESSMENT OF ROAD SCHEMES - PEARS

PEARS undertakes trip-based assessments of changes in travel time costs and vehicle operating costs derived by microsimulation. To date, link-based assessments (eg COBA) and matrix-based assessments (eg 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 models, has access to the costs of each individually modelled vehicle on the network and aggregates these to derive the overall cost.

The key parameters for undertaking a traffic and economic assessment are detailed in WebTAG, which contains specific 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 COBA/TUBA compatible table of costs discounted to a present value year, 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.

The distinguishing feature of PEARS lies in the source of the trip cost data, which comes from microsimulation models. These are able to more accurately measure changes in travel time and fuel use than traditional macroscopic traffic models, which do not have access to this level of detail and hence fail to assess some important contributors to the cost equation. An example of how this difference can be important is 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. Microsimulation can capture the detailed effect, and PEARS can translate this into a monetary value for inclusion in the overall cost benefit analysis.

Advanced microsimulation systems include 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

Figure 1: S-Paramics simulation of overtaking on a WS2+1 section of the A77, and Figure 2 : The overtaking driver's view of the same scene.

initiated when both the desire to overtake and the available gap are present.

A recent commission for Transport Scotland, on behalf of all UK government transportation departments, was designed to assist with the preparation of a new technical advice note to determine optimum scheme lengths for a highway configuration of wide single 2+1 overtaking lane (WS2+1). WS2+1 carriageways comprise the development of a third traffic lane to provide dedicated overtaking, where traffic in the opposing direction is prohibited from overtaking.

An S-Paramics microsimulation model was developed to replicate a section of single carriageway, which included a 4.5km approach, a variable length section comprising the improved overtaking, and a 10km run-out section to enable downstream benefits to be measured. The approach alternately allowed and barred overtaking, to ensure that realistic platoons would enter the study section. The model was calibrated against number plate matching surveys.

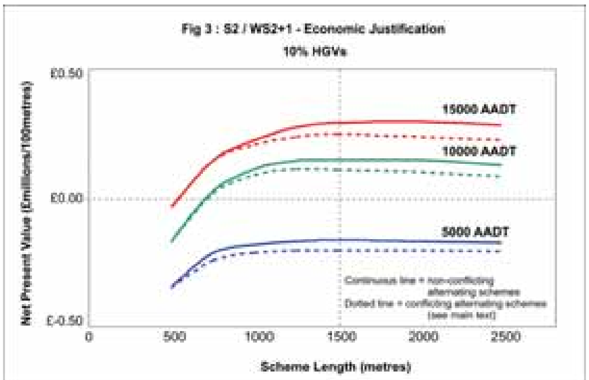

Figure 3: The measured advantage of overtaking schemes.

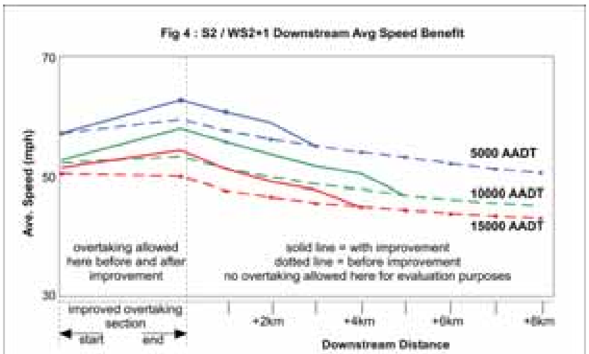

Figure 4: The impacts of downstream benefits on vehicle speeds.

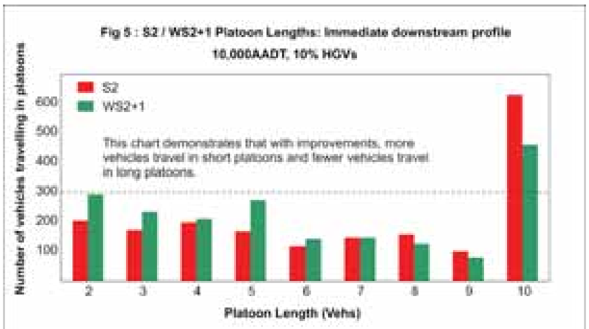

Figure 5: The impact of platoon dispersion captured by microsimulation.

Some 1500 test runs were conducted on a variety of configurations under different traffic flow regimes in order to draw broad conclusions to inform the advice note. All the test cases involved a WS2+1 comparison against a reference base of a standard S2 (7.3m) or WS2 (10.0m) carriageway. In parallel with the tests, and as part of the PEARS development programme, the system was used to evaluate the benefits of live proposed overtaking schemes on the A75, A76 and A77 trunk routes in south west Scotland.

The tests also examined the benefits which can be accrued through provision of alternating overtaking lanes. These can be conflicting, where the direction of alternate overtaking is towards the mid point of the scheme (nose to nose), or non-conflicting, where the direction of alternate overtaking is towards the ends of the scheme (tail to tail). There are significant psychological and practical differences between the two which affect platooning levels in the oncoming traffic.

Figure 3 shows an example of the economic assessment, and the measured advantage of non-conflicting schemes. The PEARS analysis applied to the microsimulation output indicated that S2 to WS2+1 is difficult to justify economically in low flow situations, that the optimum overtaking section length lies between 750m and 1,250m, and that beyond 1,250m there is little return for additional cost.

Figure 4 charts the impact of downstream benefits on vehicle speeds, and demonstrates the contribution the downstream section makes to the scheme NPV. At 10,000 AADT, the benefit in terms of increased vehicle speed is accrued for up to 5km downstream, while overtaking demand is satisfied earlier at flows of 5,000 AADT. At 15,000 AADT, the benefit is also of short duration, as overtaking vehicles soon catch up on the next platoon.

Figure 5 illustrates the impact of platoon dispersion captured by microsimulation. The analysis of the platoon profile exiting the improved overtaking section clearly indicates a reduction in the number of longer platoons in favour of those containing fewer vehicles.

By evaluating the economic benefits in detail using a microsimulation model it is possible to capture small changes in travel time and vehicle operating costs which would otherwise be lost. The PEARS cost/benefit approach enables these savings to be translated into monetary benefits. It should be noted that the main benefit of an overtaking scheme is not just felt in the area where the improvement is undertaken, but for many kilometres downstream. Simply estimating the operating benefits to vehicles within the improved overtaking section by modelling the immediate area where the work is to be done will not capture the true effects of the work.

OTHER FACTORS IN THE ECONOMIC EQUATION

The overtaking example above demonstrates how small time savings can significantly contribute towards the economic justification of a road improvement scheme when the bene-

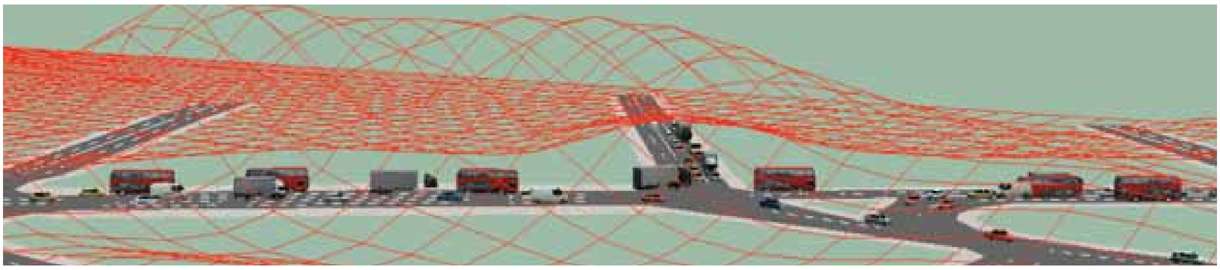

Figure 6 : The S-Paramics vehicle emissions net illustrates the formation and location of air quality black-spots.

fits are applied to where they are experienced by the road user. Vehicle operating costs also have a role to play, and these take on a greater significance where schemes are designed to minimise stop-start running. By not assessing the detailed fuel consumption across a road improvement scheme, benefits can be critically underestimated, potentially leading to its rejection on economic grounds. PEARS has the functionality to incorporate the fuel consumption calculated within the microsimulation model into its vehicle operating cost calculations. Since S-Paramics assesses the fuel used by each individual vehicle represented in a model for every half-second time step, it is able to accurately and realistically measure the consequences of stop-start driving conditions in congested road networks.

Equally significant are pollution factors, in particular carbon emissions. S-Paramics contains an emissions model which quantifies vehicle pollutants for each individual vehicle trip and is able to clearly differentiate between schemes on this basis and test adherence to National Air Quality Strategy guidelines. Given the proposals to update WebTAG Unit 3.3.5 to incorporate the calculation of carbon emissions and the potential to allocate monetary values to these, microsimulation models will be ready to include them in the economic assessment when they are published. Microsimulation also offers the unique benefit of calculating emissions based on aggregating each individual vehicle trip as opposed to calculating them based on average link speeds (as per COBA) or average matrix/Origin-Destination speeds (as per TUBA).

CONCLUSIONS

Microsimulation models have already been used to assist in the economic justification of road improvement schemes where the apparent benefits have been effectively locked away because of the difficulty of realistically representing and measuring them using traditional macroscopic software. Microsimulation methodology is well placed to properly implement DMRB and WebTAG guidance to ensure that some crucial aspects of scheme appraisal are not overlooked. The ability to accurately measure vehicle speeds is fundamental to economic scheme appraisal, and only microsimulation can differentiate between speeds in the manner required for proper reporting.