Elasticity of demand and highway scheme benefit evaluation

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DIADEM (Dynamic Integrated Assignment and Demand Modelling) software package has been recently introduced to complement the variable demand modeling process. The fundamental impetus of DIADEM is to test the robustness of highway scheme benefits and this software package is intended to be complementary to conventional demand modeling software. This paper tests a small hypothetical network of a town in the UK to compare the benefits under the current conventional methodology and under the DIADEM methodology.

1 INTRODUCTION

This paper examines the DIADEM (Dynamic Integrated Assignment and DEmand Modelling) package. DIADEM[1], at present provides interactivity with conventional traffic assignment packages CONTRAM(Taylor,1990,2003) and SATURN(Van Vliet and Hall,2004). The use of DIADEM was highlighted as a need to support the impending published guidance on Variable Demand Modelling (VADMA) to be issued by the Department for Transport (DfT) in the UK. This guidance will complement the existing Design Manual for Roads and Bridges (DMRB) Volume 12 Part 2 which focuses on Induced Traffic Appraisal.

This paper does not review the literature behind VADMA or the technical aspects of DIADEM as this literature is available elsewhere (see Mott MacDonald (2003),(2005)) but attempts to assess the implications on scheme benefits through the introduction of DIADEM.

DIADEM is intended to enhance the robustness of computed scheme benefits which are sensitive to the convergence of demand and supply functions.

This paper presents the results of a test of a small network and compares benefits from conventional runs with the benefits from runs of DIADEM under varying elasticity assumptions. Benefits are computed using Transport User Benefit Analyis (TUBA) software (Mott MacDonald, 2004). Section 2 reviews the current methodology for evaluating scheme benefits (which we term the 'conventional' approach). Section 3 introduces the revised DIADEM based evaluation methodology. Section 4 introduces a test network which serves as an input into Section 5 which illustrates the simple sensitivity test comparing the revised methodology with the existing advice and finally Section 6 draws some conclusions.

It is important to point out that while this paper focuses solely on SATURN, DIADEM is intended to be interfaced with other modeling packages.

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2 CURRENT EVALUATION METHODOLOGY

The conventional methodology for the variable demand evaluation of road schemes within the UK for a SATURN model involves the following 5 steps:

1 Skim costs from the base year validated model;
2 Carry out elastic assignments for the Do Minimum Scenario for each modeled year;
3 Carry out elastic assignments for the Do Something Scenario for each modeled year;
4 Skim Time and Distance and Output Trip Matrices for each modeled year and time period from the above assignments;
5 Use these time/distance/output trip matrices as inputs into DfT's TUBA run.

The elastic assignments for Steps 2 and 3 in the above procedure utilise the costs from the base year and this is known as the base year pivot (and this is extensively described in existing guidance DMRB Chapter 12 Part 2). In the above, we have ignored the complexities of multiple user classes. Nonetheless, this methodology elaborated above can easily be extended to handle multiple user classes.

3 DIADEM BASED EVALUATION

Methodology

With DIADEM the assignment is carried out carried out by SATURN within the DIADEM framework. In other words, no elastic assignment parameters need to be in place in the network files unlike under the conventional approach. The revised methodology is as follows:

1 Specify the elasticity parameters within DIADEM which should be the same as that which was used for the conventional SATURN elastic assignments;
2 Specify the base year validated assignment (from which DIADEM extracts the base year costs) for each time period;
3 Run DIADEM for each assignment scenario (Do Minimum and Do Something) for each modeled year;
4 Check that the converged trip matrix produced from the 'best' DIADEM iteration does not differ significantly from that produced from the last iteration;
5 The time/distance/best output trip matrices from each DIADEM run are inputs into the TUBA run.

In this approach DIADEM repeatedly calls SATURN to per-

form the assignments until demand supply equilibrium convergence is achieved or until the algorithm iteration defaults (user specified) have been reached, whichever is sooner. The above procedure implies that the user need only provide the input forecast year network files as well as providing information to the location of the base files where the base cost information will be skimmed[2].

An analogy to basic price theory economics may provide some insight into this new paradigm. In terms of demand supply economics, one may view the traffic assignment software as providing a description of the supply curve. DIADEM, on the other hand, represents the demand curve and the repeated calls to the traffic assignment software as a search for a converging point (which then may be interpreted as the intersection of the demand and supply curve).

4 DESCRIPTION OF TEST NETWORKS

The network used for the test described in this paper do not purport to represent any real road network although it is based on actual UK speed flow relationships, but is deemed to be a valid representation of actual transport planning problems encountered by transport modelers.

4.1 Base Year

This network is a small buffer network with 21 nodes, 72 links and 11 zones. Furthermore, unlike some networks used in practice, junctions are not explicitly modeled. In addition, we only model one time period for which there were 3485 trips in 1 user class in the base year of 2002.

4.2 Future Year Networks

The totally fictitious 'Do Something' network involved implementing a bypass. For simplicity, it is assumed that the Do Minimum network was taken to be the same as the base network.

4.3 Future Year Trip Matrices

We assumed that the bypass will open in 2009 and the design year for the scheme will be 15 years after opening ie 2024. These two years were the modeled years and is based on conventional traffic appraisal practice.

For simplicity, a generic growth factor (applied to all trips equally) was applied to the 2002 base matrix and Table 1 gives the factors used. Thus for a given modeled year, the reference trip matrices are the same for both Do Something and Do Minimum scenarios.

5 SENSITIVITY TESTING

Scenarios	Year	Matrix Total (pcus)	Factor Applied From Base Year
Do Something	2009	3834	1.10
Do Minimum	2009		
Do Something	2024	4357	1.25
Do Minimum	2024		

Table 1: Trip matrix details in various scenarios

5.1 Variation in Elasticity of Demand

It has been documented that benefits of any road scheme are sensitive to the elasticity of demand (Ortuzar and Willumsen (1994), Mackie and Bonsall (1989)). Hence it is believed that some useful insights may be acquired by a sensitivity test of the scheme benefits using the test networks illustrated above for both the conventional evaluation methodology mentioned in Section 2 and the DIADEM evaluation methodology of Section 3. Theoretically, the benefits of the scheme from both the conventional run (without DIADEM) and the revised run (with DIADEM) should be the same. In this paper we report on a sensitivity test which was carried out to examine benefit computations under both approaches with respect to variations in the elasticity of demand parameter for a simple constant elasticity demand function.

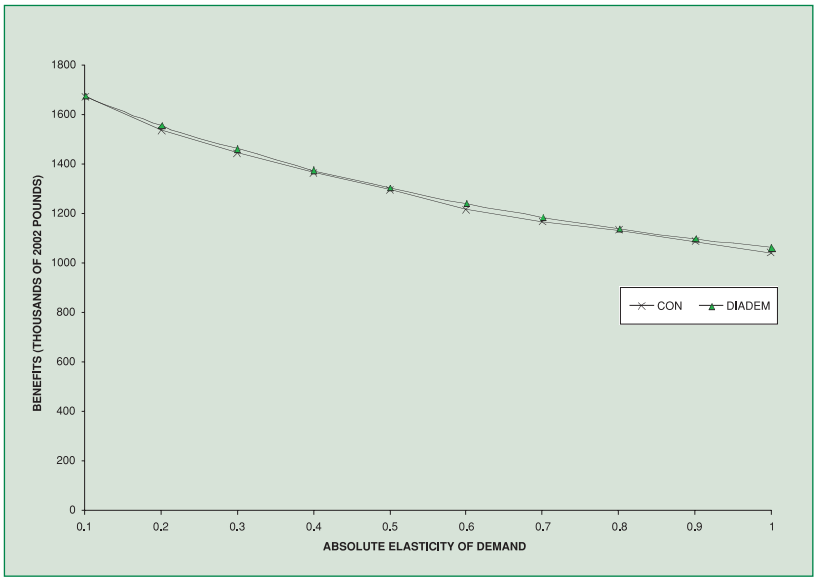

Figure 1: Comparing scheme benefits under conventional evaluation techniques and DIADEM-based evaluation techniques.

In both cases, the elasticity parameter was varied from -0.1 to -1.0 in steps of 0.1. In SATURN this is known as the 'power' parameter for MCGILL=2. Assignments were carried out using Wardrop Equilibrium assignment (Wardrop, 1952) with the stopping criteria set to a maximum of 399 iterations which provided a high degree of convergence (Van Vliet and Hall, 2004). Similarly, DIADEM runs were performed using 'Algorithm 1'[3] which is recommended in the DIADEM user manual with exactly the same elasticity parameters as used in the conventional approach.

5.2 Results

The TUBA software provides scheme benefits in 2002 values in thousands of pounds, discounted over 60 years with discount rates in accordance with HM Treasury (2003). Figure 1 illustrates the variation of the scheme benefits as the (absolute) elasticity of demand increases. In this context, the elasticity of demand measures the percentage change in trips as a result of a percentage change in generalized cost of trip making. A larger elasticity implies a larger rise in the number of trips, eroding the relief the highway scheme provides.

Figure 1 indicates that the benefits accord with economic theory. In addition, the difference in benefits computed does not seem significantly different under either approach. However, it might be more insightful to examine the relative percentage difference (RD) in benefits defined as:

$$RD = \frac{Benefits\,(DIADEM) - Benefits\,(Conventional)}{Benefits\,(Conventional)}$$

Where Benefits (DIADEM) refers to the scheme benefits computed using the DIADEM approach and Benefits (Conventional) refers to the benefits computed under the conventional approach.

Figure 2 graphs the percentage difference in benefits relative to that obtained via the conventional methodology described in Section 3. The graph shows that the percentage difference is positive. This implies the benefits are higher when computed via the DIADEM methodology.

Our numerical tests indicate that the relative difference could be as high as 2%. Obviously the extend of the differ-

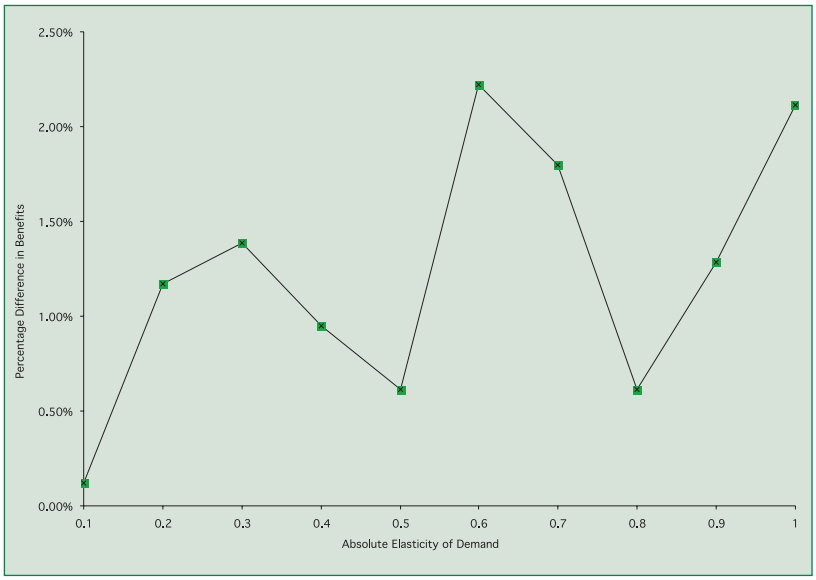

Figure 2: Relative Percentage Difference in Benefits calculated by the conventional approach and the Diadem-based method.

ence would depend on the scale of the project. Less certain however is whether larger benefits computed under DIADEM were a result of the specific nature of this network or whether the results contained herein could be generalised to other networks is a research issue of importance.

5.3 Note on Run Times

DIADEM requires a number of user specified iterations before demand and supply convergence is achieved (where it activates SATURN to carry out the assignments.). The DIADEM-SATURN process was generally fast when run on a modern Windows XP PC with a processor speed of 2800 MHz, 512 Mb of RAM and 50GB hard disk space. For this simple network, run times were approximately 2 to 3 minutes per demand elasticity value tested per network per forecast year which is fairly rapid.

6 CONCLUSIONS

This brief note has demonstrated the use of DIADEM in a simple setting, employing the revised evaluation methodology. In addition, it has shown for a simple network that the differences in benefits computed under either approach are reasonably small and we can tentatively conclude that the errors of demand-supply convergence have not overcome the effects of the benefit evaluation process and presented misleading results. This paper presents the results of tests based on a relatively new step forward in transport planning and transportation economics. While this approach is novel and the tests simplistic, there are some issues that can be highlighted at this stage.

Firstly, our sensitivity tests were run on a buffer network where convergence of both SATURN and DIADEM was not a critical issue. However, it is quite probable that for large networks with more user classes and with junctions modeled explicitly (the so called 'simulation networks'), the memory requirements and the long run times of DIADEM may make the process unduly time consuming. It is our understanding that 'batch' facilities are being developed to allow for overnight runs, if required but has not been included in the beta version as it is still under development.

Secondly, while our numerical tests indicate that the benefits from DIADEM are generally higher than that from the conventional methodology, there is no guarantee that this is indeed the case for other networks. Further research is required before more substantial conclusions on this issue can be drawn.

Finally, it is acknowledged that while DIADEM has the ability to carry out full variable demand modeling, which may include a full blown four stage transport model with feedback and involving public transport, this paper has explored only the simple elasticity approach on a purely highway based scheme. We understand that studies are currently underway that will explore these other issues in more detail.

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Acknowledgements

The author thanks Dr Dirck Van Vliet and Dr Andrew Gordon for useful comments on an earlier draft. In addition, the author would like to stress that he was not part of the DIADEM project team and the views expressed in this paper do not represent the views of the DIADEM project team or the Department for Transport. The usual disclaimer that the author remains solely responsible for all errors and omissions in this paper applies.

Footnotes

1 *DIADEM Beta Version No 2.0.16 June/2005 developed by Mott MacDonald under contract to the Department for Transport.*

2 *There is another option within DIADEM where the user can provide the cost explicitly, instead of letting DIADEM skim it. The recommended approach is to let DIADEM run the skim. See Mott MacDonald (2005) for details.*

3 *There are three algorithms for demand and supply convergence available to the user within DIADEM. Mott MacDonald (2005) recommends 'Algorithm 1' as the best performing of three (based on computing efficiency) to date.*