THE AIUTO PROJECT: YORK TEST SITE

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Abstract

The AIUTO (Assessment of Innovative Urban Transport Options) project is a Europe-wide investigation into urban transport management with emphasis on the modelling of demand management measures. The York Case Study concentrates on proposed alterations to improve the service to one of York's Park and Ride sites with the aim of promoting a mode-shift to park and ride use for commuters. The work was split between the three groups working on the project so that each applied their own models for assessing relative performances of several schemes pertaining to the proposed alterations. The purpose of this study is twofold: an assessment of the schemes and an assessment of the models used. The paper discusses how the two issues are intricately related.

INTRODUCTION

The AIUTO (Assessment of Innovative Urban Transport Options) project is a Europe-wide investigation into urban transport management with emphasis on the modelling of traffic demand management (TDM) measures. Part of this project is a case study of the York network in England which was done by groups from the York Network Control Group (University of York), the Institute for Transport Studies (ITS, University of Leeds) and the Transport Operations Research Group (TORG, University of Newcastle upon Tyne).

The York Study looks at proposed alterations to improve the service from one of York's Park and Ride sites by including a few bus lanes and implementing other bus friendly complementary measures. Those alterations are of a rather small-scale and so might be termed tactical measures as opposed to the wider strategic measures which were considered in other AIUTO case studies. For such tactical measures , it was felt appropriate not to apply demand modelling, hence this is why the models used in this study only cover the route choice and traffic representation issues. The measures tested being so small, it is unlikely that they would have any significant effects on the travel demand, and also using an elastic demand might have clouded the analysis concerning the tactical modelling carried out in this study. Tactical modelling is important since its output is often used as input for the strategic models, therefore having several alternative tactical models provided a very good opportunity to investigate the reliability and robustness of such modelling, in parallel to the assessment of the various TDM schemes tested.

Since the emphasis of the AIUTO was upon scheme testing, a set of common minimum indicators (Measures of Effectiveness or MoE's) was agreed to be produced by all test sites in order to evaluate the schemes, however some local indicators were also computed for York, as they were thought to be particularly adapted to the small tactical alterations included in the TDM schemes tested in this study.

The structure of the paper is as follows: first a rapid overview of the York test site and the TDM schemes (or packages) tested on the network, followed by a description of the various models used by all partners involved in the study. Section 4 presents the results and finally Section 5 attempts to give an analysis of the results, taking both the models and the schemes assessment into account.

Terminology, Acronyms and Abbreviations:

DRACULA = Dynamic Route Assignment Combining User Learning and microsimulation
DUE = Deterministic User Equilibrium
HOV = High Occupancy Vehicle
MoE = Measure of Effectiveness
PFE = Path Flow Estimator
STEER = Signals/Traffic Emulation with Event-based Responsiveness
SUE = Stochastic User Equilibrium
TDM = Traffic Demand Measure
YCC = York City Council

DESCRIPTION OF THE YORK TEST SITE AND THE TDM PACKAGES TO BE TESTED.

The City of York is situated in the North East of England and has an urban population of around 135,000. York District has approximately another 40,000 residents. The transport policy for the City of York is to limit the growth in car traffic so that the number of trips by private car into the City Centre during the peak hour in 2006 are no higher than 1992 levels. Excess demand for transport will be encouraged to use other, more environmentally friendly, modes of transport such as walking, cycling and public transport. Park and Ride is already making a contribution to the overall transport policy. York City Council recently decided to implement a few measures in view of improving the access to one of the Park and Ride site, as well as reducing bus journey times on a congested corridor into town. The study in the AIUTO project consists of grouping some of those measures into different packages, and then use the indicators (MoE's) produced by the models to assess the packages relative performances. The packages or schemes to be studied in AIUTO are listed in this section with explanations of the salient points of each package. To a great extent the modelling has been co-ordinated between the partners involved with the site so that the results produced are as comparable as possible. Names given in brackets refer to the column headings given for the packages in tables for ease of reference.

Base case

Base case network (BEFORE): This is the before network which is used for comparison with Packages I through IV. It is a calibrated, validated, car only network with a fixed demand for the morning peak hour of a typical week day and was supplied by YCC. The network has over 30,000 vehicles in the peak hour. The network is for private vehicles and two of York's Park and Ride routes. The network contains no bus lanes.

Package I

Bus Lanes (BUSLANES). By adding bus lanes to the park and ride route, YCC hopes to decrease travel times for inbound buses, particularly in the busy morning peak hour. Two stretches of road will be converted from mixed use (private and public transport) to being solely bus-lanes. Due to the layout of the route it is not possible to have a bus lane running the length of the route. Buses are assumed to give way to cars at the end of the bus route.

Package II

Bus Priority Signals (PRIORITY). The bus lanes will not be totally effective if, at the end of the lane, the buses are held up by having to force their way back into the oncoming traffic. Therefore this package will consider the addition of priority signals at the end of the bus lane stretches which give priority to the buses and delay the cars. This package is based upon package I with the addition of priority signals for buses. The priority signals ensure that vehicles using the bus lanes will always get a green phase when they arrive at the signals with.

Package III

High Occupancy Vehicle Lanes (HOV2). This package attempts to assess the effects of allowing bus lanes also to be used by high occupancy vehicles. The package is based upon package III (base network with bus lanes and priority signals for vehicles in the bus lane) and considers the effects of allowing vehicles with two or more passengers to use the bus lanes.

Package IV

Higher Occupancy Vehicle Lanes (HOV3) . As for the previous scenario but only vehicles with three or more passengers are allowed to use the high occupancy vehicle lane.

DESCRIPTION OF THE MODELS

Four modelling packages are used by the three UK partners. The ITS used SATURN for estimates of most performance indicators and DRACULA for detailed pollution estimation. TORG used PFE for their modelling and YNCG used their program STEER. Only the route choice dimension is modelled for all packages , route choice. Table 1 presents a summary of the models used by the modelling packages within the AIUTO framework. (Note: this represents the packages as they were used within AIUTO rather than their full capabilities. For example, STEER can be run as either stochastic or deterministic user-equilibrium and SATURN has models for mode choice and elastic demand assessment available).

Table 1: A summary of the modelling packages used on the York Test Site

	STEER	PFE	SATURN	DRACULA
Supply model (simulation)	Microscopic junctions. Macroscopic links. Dynamic.	Macroscopic Static	Macroscopic links. Cyclic Flow Profiles junctions.	Microscopic Dynamic
Demand Model (see below)	Fixed Matrix Integer values	Fixed Matrix Integer values	Fixed Matrix Real values	Fixed Matrix Real values
Assignment Model	Dynamic DUE Incremental	Static SUE Logit	Static DUE Frank-Wolfe	Routes taken from SATURN

SATURN in AIUTO

In AIUTO, the following transport models are used in the SATURN package:

Steady state deterministic user equilibrium assignment
Mesoscopic simulation of junction using cyclic flow profiles
Macroscopic flow-delay relationships on links
Fixed car trip matrix
Fixed park & ride bus routes

At the heart of the SATURN algorithm is an iteration between assignment and junction simulation. The assignment model estimates turning movements through junctions. These turning movements are fed into the simulation model which estimates flow-delay curves at junctions. These flow-delay curves are combined with the pre-defined flow-delay curves on links, and together they are used in a new assignment. In turn the new assignment provides new turning movements at junctions. This iterative process continues until sufficient convergence is achieved.

DRACULA in AIUTO

DRACULA is a microscopic dynamic traffic assignment and simulation model of traffic networks; the demand and supply sides of the model interact with each other on a day-to-day bases. For the York study only the traffic simulation part of it is used with route assignment provided by SATURN. The routes chosen by SATURN are fed to the DRACULA simulation model which, in turn, feeds its output to the DRACULA pollution estimation model. The traffic simulation of DRACULA is individual vehicle based microscopic simulation of junctions, links and lanes. Vehicles follow pre-determined fixed routes from their origins to destinations, en-route they encounter queues and traffic controls. The positions and speeds of each vehicle are updated every one second according to car-following, gap-acceptance and lane-changing rules and traffic regulations. The emission sub-model of DRACULA obtains detailed traffic condition directly from the traffic simulation. Coupled with disaggregated emission rates by driving mode (acceleration, deceleration, idling or cruising), the emission model predicts instantaneous exhaust emission and fuel consumption. The emission factors used are taken from the QUARTET Deliverable No. 2 (1992). Emission rates for three pollutants are available: CO, NOx and unburnt HydroCarbon emission. The model assumes that emission factors are constant for vehicles waiting in a queue (idling), accelerating or decelerating. For vehicles cruising at a constant speed, the emission factors are assumed to be as a function of speed.

PFE in AIUTO

TORG used their model Path Flow Estimator (PFE). The PFE is a stochastic user equilibrium model formulated as a non-linear mathematical program in the path flows variables. The solution of the program gives path flows (and consequently link flows) according to the logit route choice model. Congestion effects are taken into account through flow dependant link cost functions, and the equilibrium between travel times and flows is attained using the method of successive average (MSA) in the algorithm that solves the mathematical program. Paths are built at each iteration of the program by a least cost procedure, the Dijkstra algorithm, thus avoiding the need for paths enumeration. Even though the link costs functions utilised allow for link capacities to be exceeded (resulting in queue formation), the PFE is essentially a steady-state model which was run in this study for the morning peak hour trip matrix, without 'warming up' period.

STEER in AIUTO

The STEER modelling package uses the following modelling elements in the AIUTO study:

Dynamic deterministic user equilibrium assignment.
Microscopic junction simulation.
Fixed speed flows on links.
A fixed trip matrix which may be split between modes.
Fixed park and ride bus routes.
Assignment between modes as part of the route-choice process.

Within AIUTO, STEER is used as an equilibrating model tending toward a Deterministic User Equilibrium. The program iterates between assignment and simulation with the assignment phase, naturally, providing routes for the simulation phase and the simulation phase providing revised travel time estimates for the assignment phase. The STEER model attempts to equilibrate the network by assuming that users each attempt to minimise their costs. In the modelling presented here, departure time is fixed and the choices available to the user are mode choice and route choice. The assignment model used for AIUTO was relatively simple. On each iteration, a "shortest path" through the network is calculated for each traveller based upon the travel times of previous iterations. The travellers consider switching to a new route based upon the gain it offers over their current route. The greater the cost-saving offered by the new route the greater the chance of a driver switching to it for the next simulation iteration.

CASE STUDY RESULTS

Definition of indicators (MoEs)

Here is how some of the minimum indicators (those not self-evident) required by AIUTO were defined. All the indicators were calculated for the morning peak hour.

- Accessibility: $$A = \sum_o A_o = \sum_d P_d$$

where :

$o = 1....z$ origin zones in the network

$d = 1....z$ destination zones in the network

z total number of zones

$A_o = \sum_d c_{od}$ generalised cost necessary to reach the zone d from all the other zones

c_{od} generalised cost associated to the OD couple.

- Equity:

A situation is more unbalanced when the standard deviation of the total accessibility is higher. So an indicator of equity among zones could be the ratio between the standard deviation and the average of the active accessibilities A_o.

- Worst case of accessibility change: $\Delta A = \max_o (A_o^I - A_o^0)$, where A_o^0 and A_o^I are active accessibility of zone o in the base case and in the alternative I, respectively.
- Change in Consumer Surplus: $\Delta SC = \sum_o d_0 (\overline{C}_o^I - \overline{C}_o^0)$, where:

d_0 total demand from origin o.

$\overline{C}_o^I = \sum_{dk} p_{dk/o} C_{dk}^I$ average cost to reach all destinations with paths k in the alternative I.

$p_{dk/o}$ fraction of trips from origin o to destination d by path k.

- Congestion indicator: $$Cong = \frac{\sum_i t_i \times v_i - \sum_i ff\_t_i \times v_i}{\sum_i ff\_t_i \times v_i}$$

where: t_i is travel time on link i, ff_t_i is free flow travel time on link , v_i flow on link i.

- Rat run flow level:

As an additional indicator to those required by AIUTO, it was felt useful to have an indicator that would estimate rat runs, or flows diverting from the corridor access into town, as a result of the TDM measures. Therefore the flows on three links off the corridor were aggregated to produce this indicator.

Results

Whole network MoEs

Table 2: Whole network results

MoE	Partner	Base	Bus-Lanes	Priority	HOV2	HOV3
Total kms travelled (car)	ITS	216456	216555	216511	216564	216463
	TORG	222992	223053	223201	223163	223220
	YNCG	230330	230339	230033	226696	226368
Accessibility (pounds)	ITS	20539	20542	20624	20479	20483
	TORG	17841	17854	17874	17814	17811
	YNCG	18842	18869	18867	18842	18842
Average Speed (kph)	ITS	39.1	39.1	39.0	39.0	38.9
	TORG	42.9	42.6	42.6	42.6	42.6
	YNCG	44.8	44.7	44.6	46.2	46.1
Equity	ITS	0.124	0.124	0.125	0.123	0.123
	TORG	0.172	0.173	0.173	0.172	0.172
	YNCG	0.188	0.195	0.188	0.174	0.179
Change in Consumer Surp.(pounds)	ITS	0	-27.3	-72.0	-51.3	-63.7
	TORG	0	-46.9	-62.9	+4.4	-17.7
	YNCG	0	-29.3	-39.9	2997	2761
Worst case Acc. Change (pounds)	ITS	0	0.377	2.530	0.604	0.601
	TORG	0	0.820	0.907	0.467	0.396
	YNCG	0	18.2	24.0	5.54	5.14
Congestion indicator	ITS	0.469	0.470	0.470	0.469	0.472
	TORG	0.364	0.361	0.362	0.358	0.359
	YNCG	0.448	0.447	0.450	0.394	0.394

Within cordon MOE's

Table 3: Cordoned network results

MoE	Partner	Base	Bus-Lanes	Priority	HOV2	HOV3
Total kms travelled (car)	ITS	49851	49879	49788	49812	49802
	TORG	31240	31228	31220	31322	31325
	YNCG	23565	23409	23207	22895	22875
Average Speed (kph)	ITS	37.6	37.7	37.5	37.7	37.5
	TORG	39.7	38.7	38.5	38.5	38.5
	YNCG	26.0	26.1	25.9	27.3	28.1
Change in Consumer Surp.(pounds)	ITS	0	+6	-1.4	24.5	-3.6
	TORG	0	-2.3	-19.7	-13.3	-14.2
	YNCG	0	-8.9	-11.8	67.8	90.9
Congestion indicator	ITS	0.608	0.603	0.596	0.592	0.600
	TORG	0.575	0.548	0.557	0.550	0.550
	YNCG	1.031	0.984	0.993	0.889	0.838

York Specific detailed indicators

Table 4: York Specific detailed indicators

MoE	Partner	Base	Bus-Lanes	Priority	HOV2	HOV3
Bus inbound travel time (mins)	ITS	10.83	10.77	10.52	10.52	10.39
	TORG	8.22	7.91	7.88	7.91	7.83
	YNCG	11.80	10.65	11.81	12.23	11.81
Car inbound travel time (mins)	ITS	5.72	6.23	6.43	6.27	6.38
	TORG	4.7	5.0	5.8	5.00	5.10
	YNCG	3.44	4.17	5.17	5.17	5.17
Rat Run Flow level (vehicles/hr)	ITS	748	811	863	815	834
	TORG	1720	1825	1910	1869	1899
	YNCG	1805	1809	1913	1900	1911

Detailed Pollution modelling

Table 5: Pollution results on the cordoned network

		Package considered		
MoE	Model	Base	Bus lanes	Priority
CO (Kg)	SATURN	404	406	412
	DRACULA	720	755	748
Nox (Kg)	SATURN	88.0	88.6	89.5
	DRACULA	16.3	16.9	16.7
HC (Kg)	SATURN	72.3	72.7	73.9
	DRACULA	55.0	58.1	57.6
Fuel Consumption(litres)	SATURN	4779	4772	4809
	DRACULA	4238	4364	4353
Travel time (pcu-hours/hour)	SATURN	1290	1290	1295
	DRACULA	1175	1213	1234

RESULTS ANALYSIS

A first look at the tables above doesn't seem to indicate a great agreement in raw figures between the models. Thus the following approach for analysis was adopted:
- first look at the differences between models in the base case and try to understand how those differences might be attributed to the differing principles underlying the models.
- then look at the indicators that vary significantly across the schemes for all models and classify them as consistent and inconsistent, depending on whether their variations from the base scheme across the models are similar or not.
- attempt to assess the schemes , based on consistent and inconsistent indicators.

Differences between models in the base case

The major emphasis in this analysis is upon scheme testing. Thus, when comparing models, we are mainly interested in whether there is a variation amongst models concerning the *difference* between an MoE in the base case and a do-something case. However, Tables 2 to 5 show that there can be very large differences between the model estimates of MoEs in the base case. This section examines this issue with regard to all MoEs except for pollution and fuel consumption, which are considered in the following section. Take first of all the results on car-kms. Since all three models used the same base-case SATURN whole network data, it would be expected that the total car-kms in each model would be "similar". Examining Table 2, we can see that SATURN estimates, in the base case, a lower number of car-kms than the other two models but that the biggest difference (between SATURN and STEER) is approximately only 7% (of the SATURN total). This is a completely plausible result. Both the PFE and STEER models are more stochastic than the SATURN model in their representation of behaviour so that sub-optimal (longer than necessary) routes will be chosen in both the former models. This explanation also explains why the Equity Indicator (which is, by definition, greater if the the inequity in the network is higher) is estimated by both STEER and PFE to be at a higher level in the base case than it is for SATURN. The difference between the STEER/PFE estimate and the SATURN estimate is almost 40% (of the SATURN estimate), thus demonstrating that the Equity Indicator is more sensitive than car-kms. When we look at car-kms in Table 3 (i.e. at the car-kms on the cordoned sub-network), there is a much larger difference between the models than in the whole network case. In fact the SATURN figure is more than twice the size of the STEER figure. Our first reaction to this should be to examine some of the other indicators and see whether the model results are internally consistent; if they are not, a mistake has probably been made. In the STEER case, the average network speed is 27.2 kms per hour (compared to an SATURN figure of 37.6 kms per hour) and the congestion indicator is 0.959 (compared to an SATURN figure of 0.608). It is clear that STEER represents a much more congested situation in the cordoned network than the SATURN model; and drivers would be expected to avoid the area more in the "STEER scenario" than in the "SATURN scenario" (hence the car-kms would be lower for the former than the latter). However, given the above STEER picture of the cordoned network as being congested, an explanation needs to be found as to why the STEER estimate of Car Inbound Travel Time along Hull Road (see Table 4) is lower than the SATURN and PFE estimates. The likely explanation here is that, as a traffic microsimulation model, STEER has higher estimates of junction delays (particularly for minor movements at give-way junctions) under congested conditions. It follows that it is hard for cars to access Hull Road at any of the give-way junctions between the ring road and the city centre: as a result, Hull Road itself is relatively uncongested compared to the immediately surrounding area. If this explanation solves the apparent contradiction between MoEs, it follows then all three models are painting internally consistent pictures of the base case situation; however, the three pictures are different. From Table 5, it can be seen that the SATURN and DRACULA pollution estimates for the base case are very different. SATURN, with its less detailed representation of traffic than DRACULA, does not estimate acceleration and deceleration directly, and estimates need to be made via primary stops and secondary stops. This process is likely to give less accurate inputs to the pollution model than DRACULA.

Classification of indicators

Introduction

The main purpose of this section is to classify MoEs as either consistent or inconsistent with regard to the models used in the AIUTO York case study. The tables later in this section all show the differences between the base case values of MoEs and the do-something values. In order to make a clearer analysis, these differences are expressed in terms of difference classes rather than numerical differences. Difference classes for the whole York network and for the cordoned network as well as difference classes for "Local MoEs" are shown in Table 6.

Table 6: Definition of difference classes

Difference between base case and do-something case	Difference between base case and do-something case for local MOES	Shown in Tables
Less than 1%	Less than 5%	0
Between 1-2% (base case "better")	Between 5-10% (base case "better")	–
Between 2-3% (base case "better")	Between 10-15% (base case "better")	– –
Between 3-4% (base case "better")	Between 15-20% (base case "better")	– – –
Between 4-5% (base case "better")	Between 20-25% (base case "better")	– – – –
More than 5% (base case "better")	More than 25% (base case "better")	– – – – –
Between 1-2% (base case "worse")	Between 5-10% (base case "worse")	+
Between 2-3% (base case "worse")	Between 10-15% (base case "worse")	++
Between 3-4% (base case "worse")	Between 15-20% (base case "worse")	+++
Between 4-5% (base case "worse")	Between 20-25% (base case "worse")	++++
More than 5% (base case "worse")	More than 25% (base case "worse")	+++++

It was noted that, with regard to the whole York Network, the MoE's differed very little between the base case and the do-something cases. This is not surprising since the measures being tested are extremely localised and would not be expected to have significant effects on the whole of the York network. We therefore concentrate on the differences within the cordoned network.

Within Cordon MoEs

Table 7: Differences from the base cas on the cordoned network

MoE	Model	Base	Bus-Lanes	Priority	HOV2	HOV3
kms (car)	SATURN	0	0	0	0	0
	PFE	0	0	0	0	0
	STEER	0	– – –	– –	– –	– –
Average Speed (kph)	SATURN	0	0	0	0	0
	PFE	0	++	+++	+++	+++
	STEER	0	+++	++++	+++++	+++
Congestion indicator	SATURN	0	0	+	++	+
	PFE	0	++++	+++	++++	++++
	STEER	0	–	–	– – – –	0

Table 8: Differences from the base case: pollution indicators

MoE	Model	Base	Bus lanes	Priority
CO (Kg)	SATURN	0	0	-
	DRACULA	0	- - - -	- - -
Nox (Kg)	SATURN	0	0	-
	DRACULA	0	- - -	- -
HC (Kg)	SATURN	0	0	- -
	DRACULA	0	- - - - -	- - - -
Fuel Consumption (litres)	SATURN	0	0	0
	DRACULA	0	- -	- -

Table 7 shows differences from the base case for non-pollution indicators on the cordoned network whilst Table 8 shows differences for pollution indicators. The following comments can be made. The only model which produces significant changes from the base case in terms of car-kms is STEER, for which all the changes are negative. It is clear that the three models give extremely different pictures of the effects of the schemes. SATURN estimates no significant pollution effect for the Bus Lanes scheme but negative effects for all pollutants for the Bus Priority scheme (though the fuel consumption effects of this scheme are not significant). DRACULA estimates strongly negative effects for both schemes (and in fact estimates worse effects for the Bus Lanes scheme compared to the Bus Priority scheme).

Local MoEs

Table 9: Differences from base case (local indicators)

MoE	Model	Base	Bus-Lanes	Priority	HOV2	HOV3
Bus inbound travel time (mins)	SATURN	0	0	0	0	0
	PFE	0	0	0	0	0
	STEER	0	0	0	0	0
Car inbound travel time (mins)	SATURN	0	–	– –	–	– –
	PFE	0	–	– – – –	–	–
	STEER	0	– –	– – – – –	– – – – –	– – – – –
Rat Run Flow level (vehicles/hr)	SATURN	0	–	– – –	–	– –
	PFE	0	–	– –	–	– –
	STEER	0	0	0	0	0

From inspection of Table 9 we can see that Bus Inbound Travel Time does not change significantly for any of the models, and hence is consistent. The other indicators are inconsistent.

Assessment of TDM packages by consistent MOE's

All the consistent MoEs found in Section 4 are MoEs that do not change significantly through the introduction of the schemes. Apart from whole network MOE's (not surprising given the small scale of the schemes) this is the case for the inbound bus time . This could be seen to be surprising and in fact is arguably the most important result of the whole study. The main aim of putting in bus lanes and signalised bus priority measures to help decrease the travel time of buses. Table 10 shows that, according to all three models used, none of the schemes being tested caused a significant reduction in bus journey time. The conclusion here is that the measures being tested, *by themselves*, are not justifiable. Of course the measures being tested might be useful as part of an overall package of complimentary: however this was not being studied here. The main reason for the lack of effectiveness of the bus lane measures was simply that they were too limited. An MSc dissertation carried out in parallel to the AIUTO study (Ab Jalal, 1997) tested a more extensive bus lane scheme along the Hull Road corridor and obtained bus journey time reductions of up to 40%. Whilst the schemes were not practically realistic on the Hull Road corridor, the result gives an idea of what might be achieved on other corridors elsewhere.

Assessment of TDM packages by inconsistent MOE's.

Overview

Before assessing the TDM Packages in terms of inconsistent MoEs, it is worthwhile remembering that none of the measures had a significant effect on bus journey time. This result undermined much of the potential subtlety from assessing the various measures, as is now explained. The transport measures being tested can be put into two categories:

1. Measures which solely help buses (the Bus Lanes and Bus Priority schemes). Since the road space is not being increased, it must be assumed that such measures will generally have an adverse effect on cars.
2. Measures which help both buses and high occupancy cars (HOV lanes). These measures could be interpreted as a compromise between the do-nothing and pure bus lane measures. Since buses are high occupancy vehicles, they are helped by the HOV lanes. However, some of the negative effects on cars from the lanes are reduced by allowing some cars (the most efficient in terms of occupancy) on to the HOV lanes.

If measures of type (1) are predicted to be successful in terms of reducing bus time, there are two approaches that can be taken, depending on the strength of this success. If the benefits are strong enough, the priority measures should be exclusively aimed at buses. If however, such measures cannot be justified to be of overall benefit to society, there is a strong case for introducing measure type (2).

In the AIUTO York case study it was anticipated a priori that, after getting the model results, a discussion would take place which weighed up bus user benefits against car user benefits. Such a discussion would mainly be between the do-nothing (base case maintenance) approach and implementing bus lanes, with HOV lanes being considered as a compromise solution. However, none of the measures led to a significant improvement in bus travel time and the basic a priori hypothesis was undermined. In these circumstances, we are faced with the question "which out of the measures is least bad?". In order to perform this analysis efficiently we compare schemes that differ by only one factor, since if two factors are involved we are not clear which factor is making the most important difference. For example, take the Bus Lanes scheme and the HOV schemes. The Bus Lanes scheme does not include priority traffic signalling whilst the HOV schemes include the same priority signalling as the Bus Priority scheme. When comparing the Bus Lanes scheme with the HOV schemes it is not clear whether differing results arise from the priority traffic signals or the use of the lane by HOV cars.There are thus two separate analyses: a comparison of the Bus Priority Scheme and the HOV schemes and a comparison of the Bus Priority Scheme with the Bus Lanes Scheme

A comparison of the Bus Priority Scheme and the HOV schemes

Due to unavailability or lack of usefulness of indicators, the comparison of the Bus Priority Scheme and the HOV schemes is in terms of: Car Inbound Travel Time along Hull Road (Table 9); Rat Run Flows (Table 9); and Within Cordon Veh-kms (Table 7). With regard to these three indicators, all three models produce the following results. The Bus Priority scheme is never better, but sometimes worse, than the HOV3 scheme. The HOV3 scheme is never better, but sometimes worse, than the HOV2 scheme. These results could have been predicted a priori: any interesting use of them is inappropriate due to the lack of change in the Bus Inbound Travel Time Indicator (as mentioned above).

A comparison of the Bus Priority Scheme and the Bus Lanes Scheme

We can compare the Bus Priority scheme and the Bus Lanes scheme in terms of: the three MoEs given in the above Section ; and the MoEs of CO, NOx, HC and Fuel Consumption. The results here are more interesting here in the sense that they are less predictable in an a priori sense.With respect to the local MoEs (Table 10), all models predict that the Bus Priority Scheme is either as bad as or worse than the Bus Lane Scheme. However, in terms of the Within Cordon MoEs, the picture is more complex. According to MoEs predicted by SATURN and PFE, the Bus Priority Scheme is always either as bad as or worse than the Bus Lane Scheme. However, according to MoEs predicted by DRACULA and STEER, the result is reversed: the Bus Lanes scheme is always as bad as or worse than the Bus Priority Scheme. When considering this difference, it should be remembered that there are two traffic signal elements to the Bus Priority scheme. The first element, which gives it its name, is the bus priority measure at the end of the longer (740 metres) stretch of bus lane. From the point of view of cars, this measure must have negative effects, when compared to the Bus Lanes scheme (in which cars have right of way over buses from the bus lane at this point). However, the other signal measure (the alteration of the junction at the end of the short bus lane from a priority junction to a signalised junction) is not so clear cut. The benefits to cars ascribed to the Bus Priority scheme (compared to the Bus Lanes scheme) by STEER and DRACULA are probably due to the better access on to Hull Road from the minor arm at this junction. As said above, traffic microsimulation models can emphasise delays to minor traffic movements at priority junctions: such delays are likely to be reduced through putting in traffic signals which ensure that such movements get right of way for at least part of the time.

An important general point arises from this discussion. Traffic microsimulation models are the "natural" models to represent reactive traffic signal schemes: less detailed traffic models can only represent the average effect of the measures. If there is uncertainty about the effect of a traffic signal measure (as in the York case study), the traffic microsimulation should be believed. On the other hand, great care must be taken that such a model is properly calibrated for estimating delays to minor traffic at priority junctions, or else the positive effects of a traffic signal scheme are likely to be exaggerated.

CONCLUSIONS

Policy conclusions

As reported in Section 4, the main conclusion of this modelling exercise was that the schemes as defined were not sufficiently strong enough, **by themselves**, to have a significant improvement on bus journey time. Given that the schemes were predicted to have negative effects on car traffic, this could be seen as a disappointing result. However, the positive conclusion to be drawn from the exercise is that bus lane and HOV lane schemes should be much larger in scale in order to provide the necessary reduction in journey time to encourage people to switch mode from single-occupancy cars. This result confirms the basic premise that strategic policies rather than aggregates of local policies are required in order to get overall city-wide results. However, bus lane schemes and HOV schemes can of course form elements in an integrated strategic policy. Interesting indications were given on the differences between bus lane schemes with and without signalised priority for buses, and on whether to allow high occupancy cars on to bus lanes. However, the ranking of such schemes cannot be decided in an abstract sense: it is dependent upon the other measures in the package being implemented.

Modelling conclusions

There were two main modelling foci in the study:

1. The difference between deterministic user equilibrium (DUE) and stochastic user equilibrium (SUE).

2. The difference between traffic microsimulation models and less detailed models of traffic

With regard to (1) criteria can be laid as to which is the more appropriate tool given certain circumstances. However, model-users are often convinced that only one approach is correct; i.e. they are committed adherents to either one of DUE or SUE. Given this, it is useful to make comparisons to examine whether the two types of model create essentially different output. As far as the York case study is concerned, there was little difference (of importance) in results from SATURN (DUE) and PFE (SUE). The bigger model differences concerned issue (2). The conclusions from the case study with respect to (2) are that traffic micosimulation models should be used for the following purposes:

- Assessment of the effects of reactive traffic signal schemes
- Accurate estimates of pollution
- Accurate estimates of (good) safety indicators

With regard to pollution estimates in particular:

- If accurate absolute (as opposed to relative) estimates of pollution are required by a strategic model, it is highly desirable if the pollution sub-model of the strategic model is "calibrated" by a microsimulation model
- Research needs to be conducted to examine the differences between different sets of pollution coefficients, and to make recommendations as to which set is appropriate to specific circumstances.

If, though, a traffic microsimulation model is to be used it must be properly calibrated with respect to delays of traffic on minor arms at give-way junctions.On the other hand, if assessment does not involve any of the above issues, it is sufficient to use either a macrosimulation traffic model (PFE) or a mesosimulation traffic model (SATURN).

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