DEVELOPMENT OF BAT (BUS PRIORITY ANALYSIS TOOL)

Presenter: Michelle Harvey, MUrbDes, BPlan(Hons), BA(Geogr), GNZPI, AMSIP
Senior Transport Planner, AECOM Auckland
michelle.harvey@aecom.com

Andrzej Tomecki, MSc(Eng)(Transp), ME(Struct), CPEng, MIPENZ, FCILT, FITE
Principal Transport Analyst, AECOM Auckland
andre.tomecki@aecom.com

Carolyn Teh, MEngSc(Hons), BE(Civil)(Hons), GIPENZ
Transportation Engineer, AECOM Auckland
carolyn.teh@aecom.com

INTRODUCTION

In 2010 AECOM were appointed by New Zealand Transport Agency to research the development of a tool for assisting Road Controlling Authorities in selection of bus priority treatments appropriate for given road and traffic situations.

The principal project objective was to develop a procedure, which would be practical, easily accessible and which could easily be disseminated to end users.

The work concentrated on the development of a set of analytical algorithms for the assessment of the effectiveness of the various types of the bus priority treatments at the intersections and on road segments. This analytical model was used to develop a computerised procedure, which would be able to meet the project objective.

The computerised procedure analyses a raft of bus priority treatments, rates them in the order of priority according to their suitability for a given situation, and finally displays the two most appropriate treatments. This procedure has been named Bus Priority Analysis Tool (BAT).

BAT is unique in that it has been specifically designed and developed for this purpose using as its basis the Microsoft Excel 2007 platform with Visual Basic for Application (VBA). BAT is therefore a dedicated product to be distributed by NZ Transport Agency, which cannot be obtained commercially off shelf.

LITERATURE REVIEW

COMPARATIVE ANALYSIS OF BUS PRIORITY TREATMENTS

The first task of the literature review was to establish whether there were or are any international attempts to compare different bus priority treatments with each other. The review revealed numerous well documented studies where the performance of individual bus priority treatments was assessed by computer simulation.

The most appropriate tool for the analysis of performance of a priority treatment is microsimulation. For instance, Davol (2001) of MIT used microsimulation for modelling public transport signal priority strategies, Gan et al (2002) modelled bus lane preferential treatments, Liao (2006) modelled bus signal priority based on GPS, etc.

Nevertheless, a comparative analysis of different bus priority treatments and the identification of the appropriate treatments for a given situation have not been documented in the literature. Therefore BAT is a pioneering development.

BUS PRIORITY TREATMENTS APPLIED IN NEW ZEALAND AND OVERSEAS

The second task was to identify the types of bus priority treatments applied locally and internationally. This was a general literature review, which identified over 20 types of treatments.

Each of these treatments was thoroughly scrutinised by the project team. The decision criteria for selection or rejection of the treatment for the further investigation were whether:

- the treatment was commonly applied
- the appropriate conditions for its installation existed in New Zealand
- it could easily be adopted to the New Zealand conditions, and
- the cost of the treatment was not excessive.

As a result eleven bus priority treatments were selected for the further analysis. These comprised five intersection priority treatments shown in Figure 1 and six road segment treatments shown in Figure 2.

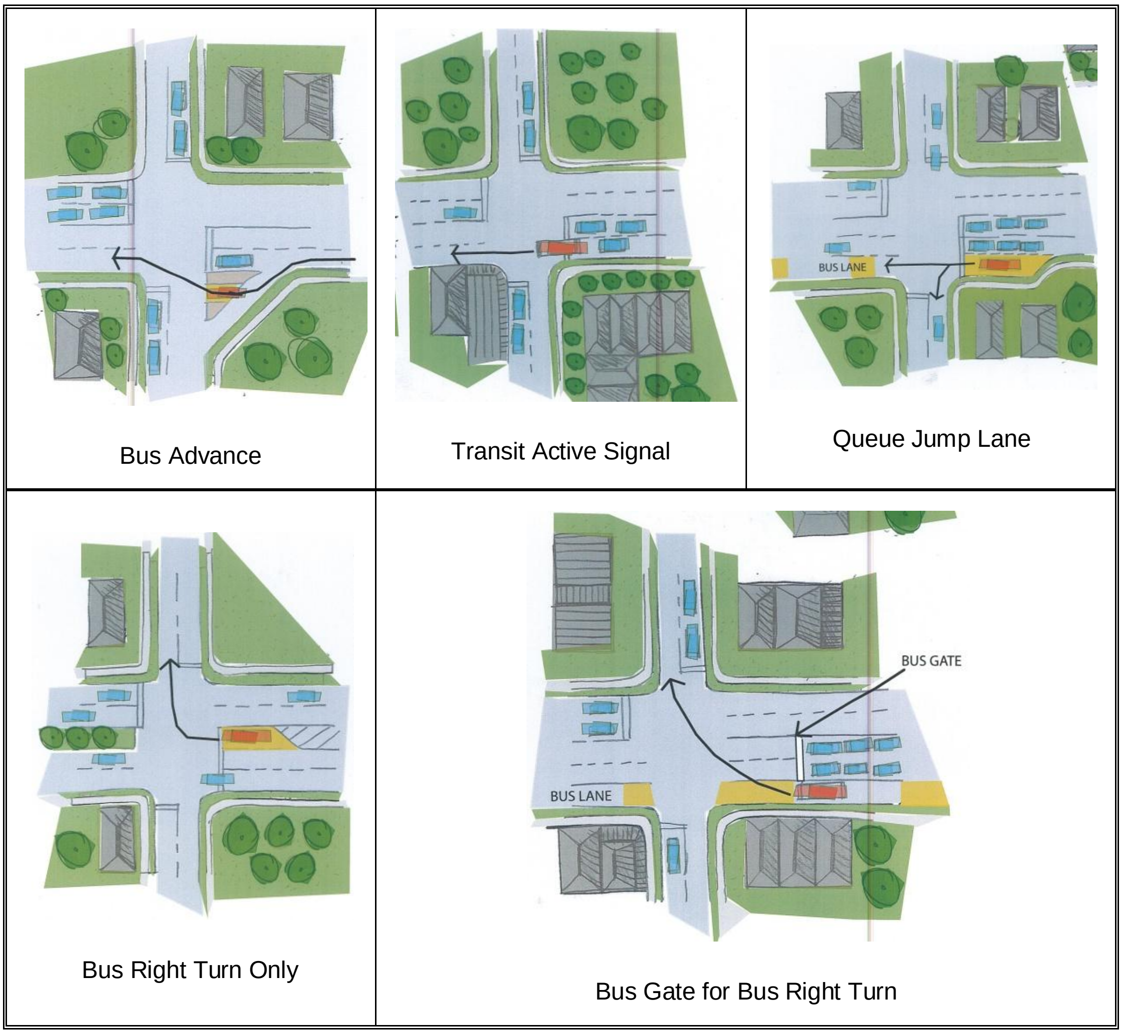
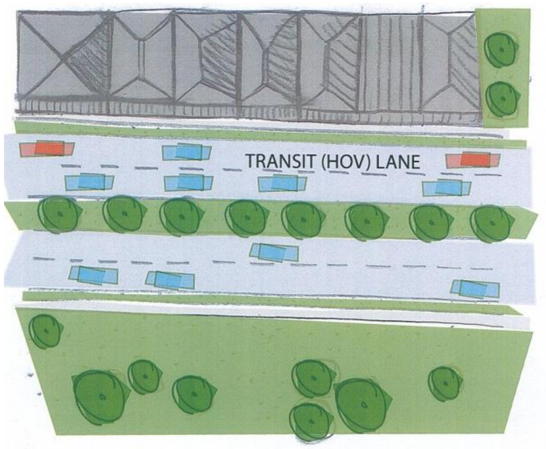


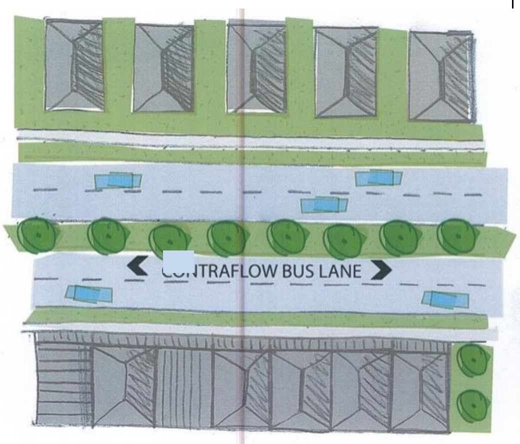
Figure 1. Intersection Bus Priority Treatments

Some of these treatments have already been applied in New Zealand, while the remaining treatments are potentially suitable for implementation here.

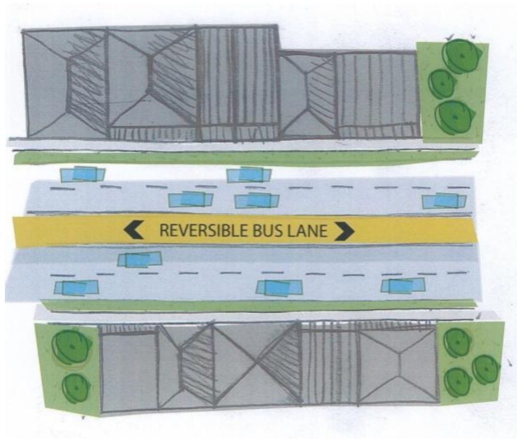
With-flow Bus Lane



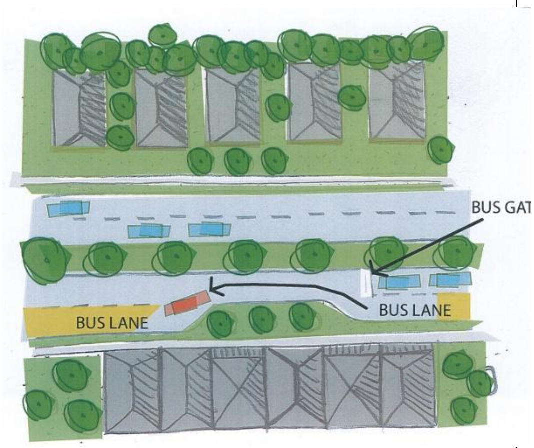
Transit Lane (HOV / T2 /T3)



Contra-flow Bus Lane



Reversible Bus Lane



Bus Gate

Figure 2. Road Segment Bus Priority Treatments

PERFORMANCE OF THE SELECTED TREATMENTS

The final task of the literature review focused on the quantified performance measures of the selected bus priority treatments. The purpose of this task was to gather material for the development of the analytical model.

The accuracy of the output of the algorithms relies heavily on robust default values. The default values of interest were the reduction of delay to buses and the increased delay to other vehicles. These values are different for each of the bus priority treatments.

Several publications provided useful data, for example, Gardner *et al* (2009) produced information on the performance of the bus priority at traffic signals. The performance of buses and general traffic at intersections equipped with Transit Signal Priority was studied by Barton (2003), Jepson *et al* (1999) and Liao (2006). Christian Bodé (2010) supplied information on the benefits of queue jump lanes for buses.

Bauer *et al* (2005) produced a comparison of the performance of the High Occupancy Vehicle (HOV) Lanes with Bus Lanes and general purpose traffic lanes. Australian Transport Council (2009) reported on the patronage growth rates on the Liverpool-Parramatta Transitway, while Vukan Vuchic (2007) observed high annual growth rates for many North American and European cities.

Shannon Boorer (2010), Shannon Ussher (2010) and Gravitas (2010) provided insights into the performance of some of the bus lanes in New Zealand, while Nee *et al* (2002), and Kwon and Varaiya (2007) analysed the performance of the HOV (T2 and T3) lanes.

As a result of this task of the literature review the project team were able to identify a range of values measured on site as well as those obtained from the computer simulation studies. Due to a wide distribution of the reported data, it was decided to define the useable ranges within the mean, median or mode values.

These values are presented in Table 1. The last column in the table shows the values used for building the algorithms in the analytical model. Although these values fit mainly within the ranges identified in the literature, in some cases it seemed plausible to adopt more conservative values outside the ranges. Such decisions were substantiated by the observation of local traffic and supported by the research Steering Group.

It has to be noted that in spite of a comprehensive search the meaningful conclusions could be drawn with regard to the Transit Active Signals (signal pre-emption), bus Queue Jump Lanes, with–flow Bus Lanes and T2/T3 Transit Lanes only. The literature review has not found sufficient data concerning the impacts of other types of bus priority measures.

Table 1: Performance Measures of Bus Priority Treatments

Bus Priority Treatment	Performance Measure	Unit	Range or Average	Adopted Value
Transit Active Signal	Bus delay reduction	(s/bus)	7.5 – 9.0	7.2
Transit Active Signal	Main road delay reduction	(s/veh)	1.5	1.5
Transit Active Signal	Side road delay increase	(s/veh)	3.0 – 3.6	3.0
Queue Jump Lane	Bus delay reduction	(s/bus)	43 - 69	5.0
With-flow Bus Lane	Bus delay reduction	(s/bus-km)	49 – 65	35.0
With-flow Bus Lane	Other traffic delay increase	(s/veh-km)	28 – 34	33.0
T2 or T3 Transit Lane	HOV delay reduction	(s/veh-km)	29 - 69	26.0
Package of treatments	Time variability reduction	(%)	8 - 50	43.0
Package of treatments	Annual modal shift	(%)	5 - 8	2.0

ANALYTICAL MODEL

INTRODUCTION

The analytical model is the engine of this research. It tests the effectiveness of bus priority treatments. It contains a set of algorithms, which enable to estimate the benefits of the potential bus priority treatments in the context of the existing situation on site.

The development of the analytical model is a theoretical work based on real-life inputs obtained from the literature, surveys and calculations using probabilities and the values of delays, saturation flows, traffic signal splits, and other operational characteristics observed on surveyed major arterials.

By comparing the effectiveness of the selected treatments, the analytical model selects the most appropriate treatment for a given situation.

KEY PERFORMANCE INDICATORS

The Key Performance Indicators (KPIs) are an important component of the analysis, because they enable the decision maker to influence the model to identify the most appropriate treatment to meet the preset decision maker's objective. There are four KPIs:

1. overall bus and car traveller delay
2. reduced car growth rate over 10 years
3. lane person throughput in 10 years
4. cost of vehicle emission

The KPIs are allocated a percentage weight totalling 100%. In most cases a different bus priority treatment would be appropriate for, for example, minimizing the overall travel time than for reducing emissions.

MODEL INPUT

There are two types of input data – site specific and general. The site specific data, such as traffic volumes, number of buses, cost estimates of the potential treatments, project budget, lane configuration or road segment length, are well known to the end user and have to be provided by them.

General input data have been provided by the project team as default values, because the user will not be familiar with most of them. These data concern mainly the performance measures of different treatments. Some of these measures have been shown in Table 1. There is an option for the user to over-ride some of the default values, when the user is able to provide more accurate site specific data.

ANALYTICAL ALGORITHM

The analytical algorithm was designed to:

- screen the input data to identify the applicable alternative treatments
- analyse the benefits of the treatments
- select the appropriate treatment and an alternative treatment, and
- calculate a rough Benefit Cost Ratio (BCR)

The initial screening of the input data allows eliminating the treatments which are inappropriate in a given situation. For instance, if there are no right turning buses, the bus right turn treatments are excluded from the analysis. The treatments not rejected by the screening process constitute the sample to be analysed.

The benefits of the bus priority treatment are based on the estimate of the reduced travel time or delay to the bus passengers (or all travellers in the transit lane), and the increased travel time to other travellers. The total of these travel times indicates how successful the proposed treatment is expected to be.

The algorithm calculates the impact on all vehicles on each approach to the intersection, or on the bus/transit lane users and the general purpose traffic lane users. The analysis is comprehensive, interrogating vehicle arrivals on red and on green, at the end of the green phase (where a green time extension will allow additional vehicles through), on the opposite approach and on the side roads. Each of the approaches at the intersection is analysed separately and the total effect on the intersection is obtained by totalling the individual impacts.

MODEL OUTPUT

The model selects and displays two treatments deemed to be appropriate for a given situation: the appropriate bus priority treatment (the highest ranking) and the alternative treatment (ranking the second highest). The magnitude of the benefits is not shown. In addition to the benefits of the treatment the algorithm produces an economic indicator: an indicative Benefit Cost Ratio for the intersection treatments and a total cost for the transport corridor treatments (with the warning if it exceeds the budget).

It has to be recognised that in this work BCR is an add-on rather than the essence. The reason for this is that the inputs to the economic indicator are rough. The cost estimates will be provided by the user and the research team do not have any means of controlling the accuracy of these estimates. This is one of the reasons why the economics are excluded from the treatment selection process, and the BCR produced by the model is indicative only. For the same reason the assessment of the incremental Benefit Cost Ratio between the treatments deemed “appropriate” and “alternative” was omitted from the model.

LIMITATIONS OF THE ANALYTICAL MODEL

The researchers acknowledge that the model is only a first generation application tool developed on the basis of the available existing data. It identifies and prioritises a number of treatments deemed appropriate for more detailed appraisal through Project Feasibility or Scheme Assessment Report work. Since the application of bus priority treatments is gaining momentum on a national scale, it can be expected that there would be an increasing number of technical staff involved in bus priority treatments, whose experience in this field may be limited. The model is intended to be a practical tool for these users.

In general, the model provides a simplified procedure to identify appropriate bus priority treatments for a given situation, but there are numerous things that BAT does not do. This includes:

- the model is not a microscopic simulation model and therefore cannot simulate the performance of individual vehicles and does not have the capability of taking into consideration the degree of saturation, speed/volume relationship, queue building and dissipation etc.
- the model is not an economic evaluation tool, it therefore is not a substitute for the EEM economic evaluation procedures and does not materially reduce the overall extent of work required at the PFR/SAR stage to satisfy the NZTA requirements. The inputs to BAT are

rudimentary and the resulting BCR is indicative. The economic considerations are not part of the process for selecting the appropriate treatments.

- the model does not analyse the interface between intersection and road segment, as it is based on two separate modules – the intersection and the road segment. This means that the distance between the end of the road segment treatment and the intersection treatment is not taken into consideration. For instance, a with-flow bus lane runs full distance between intersections and is analysed as a link between two intersections.

COMPUTERISED PROCEDURE

Bus Priority Assessment Tool (BAT) is a computerised tool kit developed as the product of this research project on the basis of the analytical model discussed above. BAT is created in Microsoft Excel 2007 with built in macros developed using Visual Basic for Applications (VBA). The details are presented in the BAT user manual (AECOM, 2011).

As an illustration, some of the BAT screens are presented in Figures 3, 4 and 5:

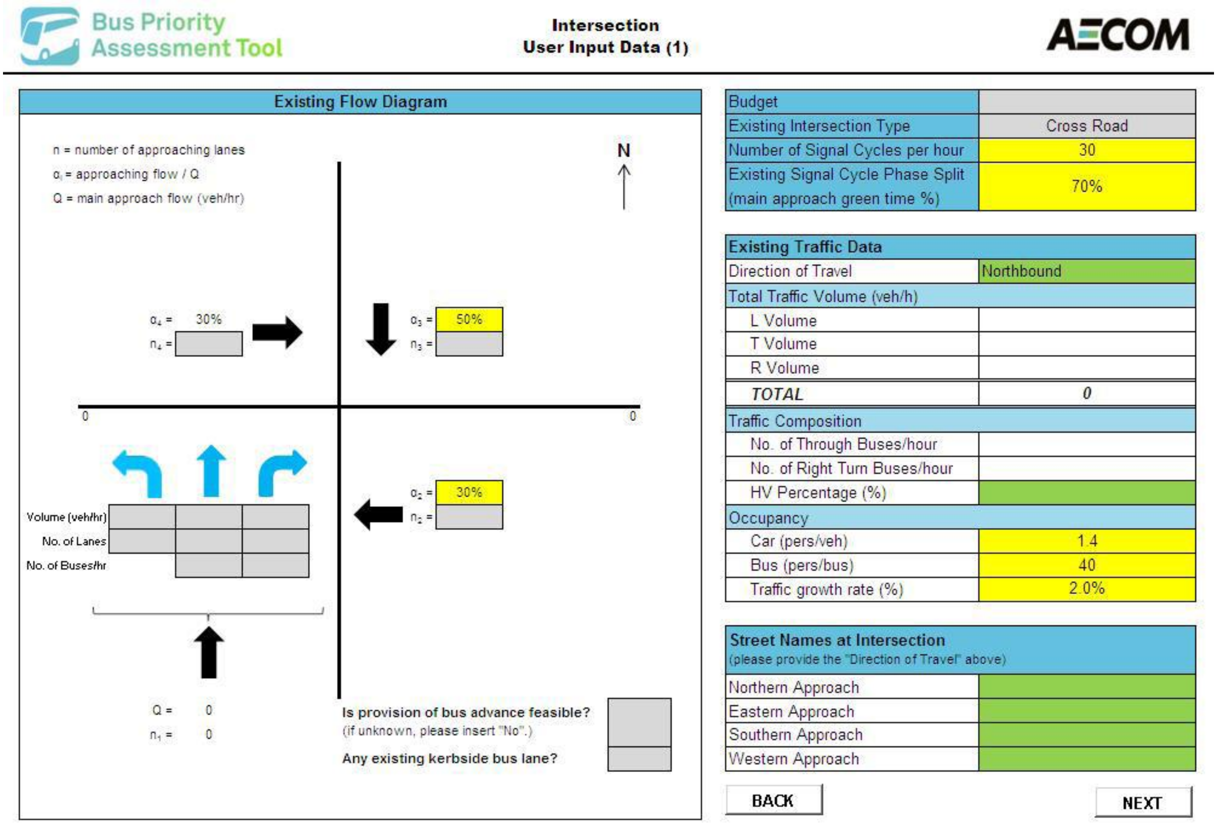
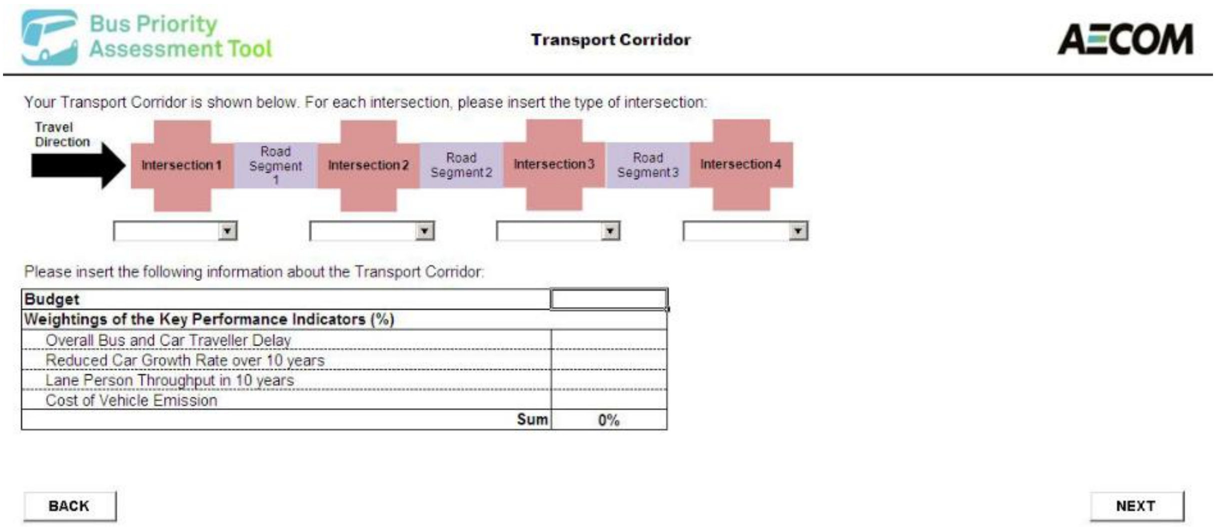


Figure 3. Input Screen - Intersection


Bus Priority Assessment Tool

Transport Corridor

Your Transport Corridor is shown below. For each intersection, please insert the type of intersection:

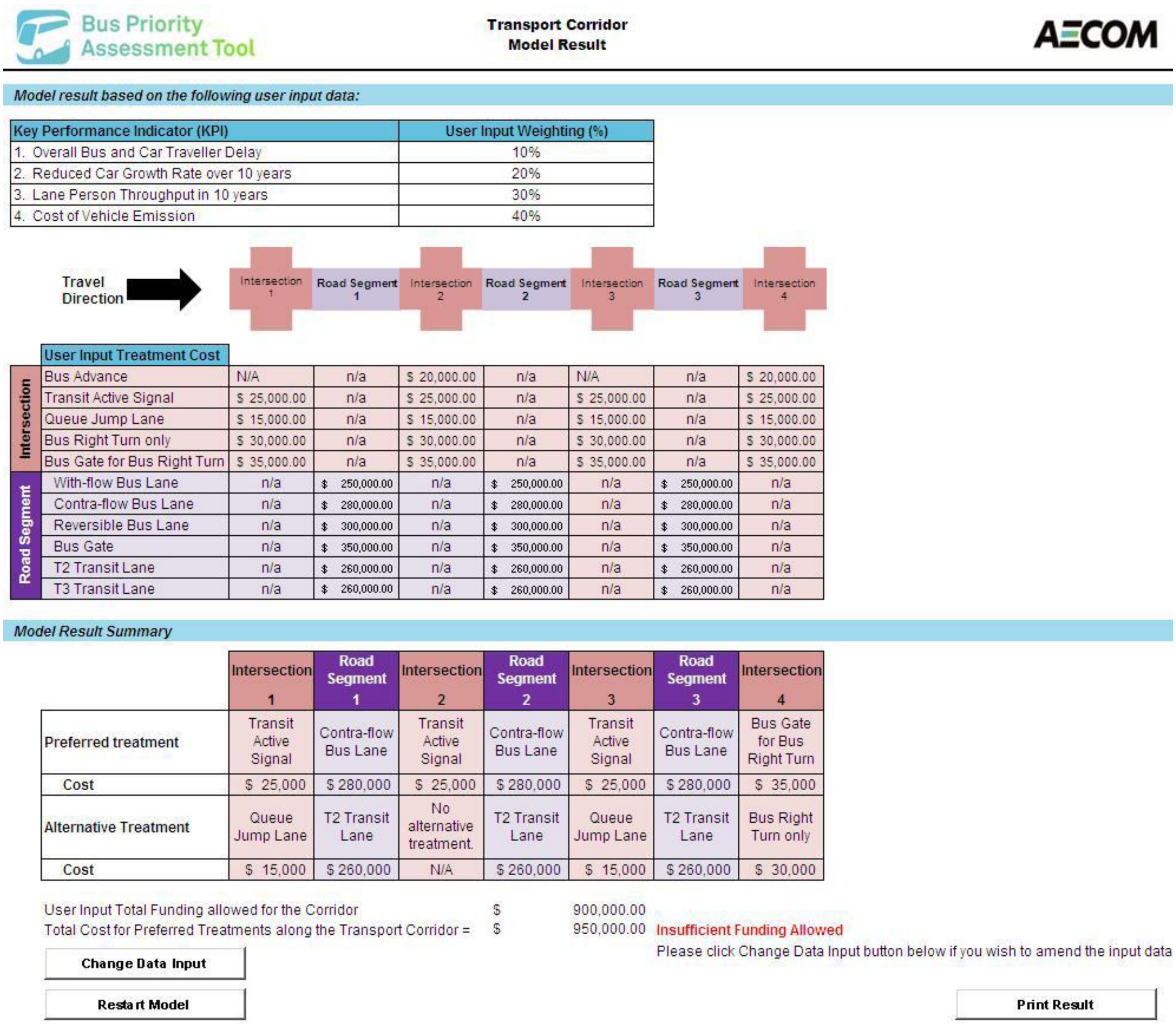
Travel Direction → Intersection 1 | Road Segment 1 | Intersection 2 | Road Segment 2 | Intersection 3 | Road Segment 3 | Intersection 4

Please insert the following information about the Transport Corridor:

Budget	
Weightings of the Key Performance Indicators (%)	
Overall Bus and Car Traveller Delay	
Reduced Car Growth Rate over 10 years	
Lane Person Throughput in 10 years	
Cost of Vehicle Emission	
Sum	0%

BACK NEXT

Figure 4. Input Screen – Transport Corridor


Bus Priority Assessment Tool

Transport Corridor
Model Result

Model result based on the following user input data:

Key Performance Indicator (KPI)	User Input Weighting (%)
1. Overall Bus and Car Traveller Delay	10%
2. Reduced Car Growth Rate over 10 years	20%
3. Lane Person Throughput in 10 years	30%
4. Cost of Vehicle Emission	40%

Travel Direction → Intersection 1 | Road Segment 1 | Intersection 2 | Road Segment 2 | Intersection 3 | Road Segment 3 | Intersection 4

	User Input Treatment Cost	Intersection 1	Road Segment 1	Intersection 2	Road Segment 2	Intersection 3	Road Segment 3	Intersection 4
Intersection	Bus Advance	N/A	n/a	$ 20,000.00	n/a	N/A	n/a	$ 20,000.00
	Transit Active Signal	$ 25,000.00	n/a	$ 25,000.00	n/a	$ 25,000.00	n/a	$ 25,000.00
	Queue Jump Lane	$ 15,000.00	n/a	$ 15,000.00	n/a	$ 15,000.00	n/a	$ 15,000.00
	Bus Right Turn only	$ 30,000.00	n/a	$ 30,000.00	n/a	$ 30,000.00	n/a	$ 30,000.00
	Bus Gate for Bus Right Turn	$ 35,000.00	n/a	$ 35,000.00	n/a	$ 35,000.00	n/a	$ 35,000.00
Road Segment	With-flow Bus Lane	n/a	$ 250,000.00	n/a	$ 250,000.00	n/a	$ 250,000.00	n/a
	Contra-flow Bus Lane	n/a	$ 280,000.00	n/a	$ 280,000.00	n/a	$ 280,000.00	n/a
	Reversible Bus Lane	n/a	$ 300,000.00	n/a	$ 300,000.00	n/a	$ 300,000.00	n/a
	Bus Gate	n/a	$ 350,000.00	n/a	$ 350,000.00	n/a	$ 350,000.00	n/a
	T2 Transit Lane	n/a	$ 260,000.00	n/a	$ 260,000.00	n/a	$ 260,000.00	n/a
	T3 Transit Lane	n/a	$ 260,000.00	n/a	$ 260,000.00	n/a	$ 260,000.00	n/a

Model Result Summary

	Intersection 1	Road Segment 1	Intersection 2	Road Segment 2	Intersection 3	Road Segment 3	Intersection 4
Preferred treatment	Transit Active Signal	Contra-flow Bus Lane	Transit Active Signal	Contra-flow Bus Lane	Transit Active Signal	Contra-flow Bus Lane	Bus Gate for Bus Right Turn
Cost	$ 25,000	$ 280,000	$ 25,000	$ 280,000	$ 25,000	$ 280,000	$ 35,000
Alternative Treatment	Queue Jump Lane	T2 Transit Lane	No alternative treatment.	T2 Transit Lane	Queue Jump Lane	T2 Transit Lane	Bus Right Turn only
Cost	$ 15,000	$ 260,000	N/A	$ 260,000	$ 15,000	$ 260,000	$ 30,000

User Input Total Funding allowed for the Corridor $ 900,000.00
Total Cost for Preferred Treatments along the Transport Corridor = $ 950,000.00 Insufficient Funding Allowed
Please click Change Data Input button below if you wish to amend the input data

Change Data Input
Restart Model
Print Result

Figure 5. Output Screen – Transport Corridor

The user manual covers the following topics: software requirement and settings, the concept of the BAT, information required before using BAT, the step-by-step interface guide, and Frequently Asked Questions (FAQ).

CONCLUSIONS

The development of a procedure to analyse a range of bus priority treatments and select an appropriate one for a specific situation is a pioneering work, and as such sets the base for the further development. It does not provide all the answers.

The research team has developed a “live” decision assisting tool available as a desktop application. It is an easily used and disseminated computerised application for practitioners. This has been achieved through the development of Bus Priority Assessment Tool (BAT). It is envisaged that after its release by NZTA BAT will be tested by end users and their feedback will be used for further refinements of the model and computerised process.

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