TECHNICAL PAPER

GETTING MORE FROM OUR ROADS: AN EVALUATION OF MANAGED LANES ON ARTERIAL ROADS

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ABSTRACT

With increasing demand for travel and limited opportunities for increasing capacity within urban areas there is increasing pressure to make more effective use of the capacity available. One approach is the introduction of "managed lanes" where only particular classes of traffic, typically buses and high occupancy vehicles are permitted to use the managed lane.

Vehicles eligible to use managed lanes typically represent only a limited part of the total traffic flow, resulting in lower and more reliable travel times for those vehicles. However where existing road space is reallocated, other traffic may face increased congestion as the capacity available for this is reduced. Users may respond by changing their behaviour to take advantage of improved travel conditions in the managed lane.

Because the setup costs of managed lanes are typically small, their economic assessment therefore depends critically on whether the reduction in costs for the managed traffic is greater than any increase for the remaining traffic

This paper considers evidence on these issues using NZ data and international research and outlines a systematic approach and analytical modelling techniques for the assessment of managed lanes on arterial roads.

INTRODUCTION

With increasing demand for travel within the major urban areas and limited opportunities for increasing roadway capacity, there is growing pressure to make more effective use of the infrastructure that is currently available. A number of approaches can be utilised, including minor works to improve lane use or to add capacity, traffic signal optimisation and more effective management of the traffic streams. More effective management can be achieved either by managing the traffic streams as a whole through classic TDM approaches including ramp signalling and road pricing or by measures to treat different components of the total traffic flow differently and give priority to "high value" traffic.

Typically this is achieved through the introduction of "managed lanes" where only particular classes of traffic are permitted to use parts of the available highway capacity in a managed or high occupancy vehicle (HOV) lane and the rest of the traffic has to share the remaining general traffic lane or lanes. There are a number of ways of defining the types of traffic which are permitted to use the managed lane, but these will typically include high value vehicles including buses, high occupancy private cars and in some cases, freight vehicles.

Eligible vehicles typically represent a limited part of the total traffic flow, and their allocation to a managed lane typically results in lower and more reliable travel times for those travelling in the managed lane. However where existing road space is reallocated rather than new capacity provided (as is often the case within existing urban areas), other traffic which is not permitted to use the managed lane may face increased congestion as the road space available is reduced.

The paper brings together two separate work streams undertaken for NZTA. The first was an investigation undertaken as part of the Managed Lanes Project in Auckland where the outline of an evaluation spreadsheet was developed to assess the impacts of the introduction of managed lanes on specific routes, and some of the emerging issues were identified. The second is a research project for NZTA looking at the development of more general and comprehensive guidelines for the introduction of managed lanes on arterial roads. The research project includes the development of analytical techniques to provide a guide to planners and engineers as to the suitability of a managed lane, and what classes of vehicles should be allowed to achieve the network objectives.

OBJECTIVES OF THE RESEARCH

- Develop a knowledge database of experience locally and internationally.
- Understand the behavioural response to managed lanes.
- Develop a planning modelling tool to help assess whether a managed lane is appropriate, and what type of lane would be best suited.

DEFINITION OF MANAGED LANE

In the New Zealand context, a managed lane is a Special Vehicle Lane, defined in the Traffic Control Devices Rule (2004) as means a lane defined by signs or markings and restricted to a specified class or classes of vehicle; and includes a bus lane, a transit lane, a cycle lane, and a light-rail vehicle.

A Transit Lane is defined as means a lane reserved for the use of the following (unless specifically excluded by a sign installed at the start of the lane):

a) passenger service vehicles;

b) motor vehicles carrying not less than the number of persons (including the driver) specified on the sign;

c) cycles;

d) motorcycles.

Special Vehicle Lanes have also been provided on the Auckland Motorway ramps that allow trucks and those classes listed as eligible for a Transit Lane, to promote higher vehicle occupancy and to ensure that freight can be efficient moved on the motorway network.

MEASURES OF EFFECTIVENESS

To date within New Zealand, managed lanes have been introduced as more of a policy response, and as a consequence there are no established guidelines against which the full impacts of proposals can be assessed or their efficiency determined.

Measures for assessing the impacts of managed lanes have typically concentrated on some simple measures, such as the proportion of the vehicular or passenger flow using the managed lanes and have not considered the full impacts on the traffic stream as a whole. This paper deals with a more comprehensive approach to the assessment of the introduction of managed lanes in New Zealand particularly on arterial roads, looking at the way in which these might impact on users behaviour and whether the overall impact is likely to be positive or negative.

Performance measures considered appropriate for measuring the effectiveness of a managed lane include:

- Vehicle travel time (by class),
- Level of illegal usage.
- Person travel time or person demand for the managed lane (it is likely to carry more people than a general traffic lane?).
- Bus journey time reliability.
- Levels of Service.
- Economic cost (analysed by determining the value of vehicles by class and number of occupants)

Typically experience with managed lanes internationally has been mixed and in a number of cases HOV lanes have not been judged to be successful and have been withdrawn in the face of public or political pressure since they are perceived as not representing “good” use of available road space. In the absence of any formal evaluation tools, it may be difficult to resist this pressure, especially if the HOV lane appears to be only lightly used and there is congestion on the other lanes. This paper therefore aims to provide a more rigorous basis for their appraisal and to help identify which schemes are good and which are therefore worth defending and those which are not so good and which may not be progressed or may be progressed at a later stage.

EXPERIENCE WITH MANAGED LANES ON ARTERIAL ROADS

International Experience

International experience with HOV lanes has mainly been concentrated on freeways, where the managed lanes may only occupy a relatively small proportion of the road space and where it may be easier to manage the segregation of the traffic. However there is some experience with the introduction of managed lanes on arterials, in the US, Canada, the UK and Norway. These include:

- Australia
- Vancouver BC
- Seattle
- Leeds
- Trondheim

There has been a limited degree of monitoring of these and later in this paper we discuss some of their observed impacts.

NZ experience

In New Zealand until recently the only conventional HOV lane has been that along Onewa Road in North Shore City in Auckland which accommodates T3 vehicles and buses only during the morning peak period. However a number of additional schemes have been implemented recently, including a T3 lane on Constellation Drive in North Shore, a T2 lane along Tamaki Drive in Auckland (replacing an earlier bus only lane) and a number of motorway on-ramps in Auckland where T2 vehicles, buses and freight vehicles are able to bypass the ramps signals and gain priority access to the motorway.

FACTORS AFFECTING PERFORMANCE OF MANAGED LANES

There are a number of factors affecting performance of managed lanes, not least of which is public acceptance. Anecdotal evidence indicates that it is more difficult to convert a lane to managed lane (particularly on a congested corridor) than if the lane was to be added.

The introduction of managed lanes has two main effects:

- An allocation impact as traffic is segregated into separate lanes by class of vehicle
- A modal shift or behavioural impact.

The extent to which the objectives are achieved may depend on the level of non-compliance (violation) which can be reduced through enforcement. Initial evidence from the implementation of the motorway ramp priority lanes in Auckland indicates a violation rate of approximately 20%; however the police presence is visible with regular enforcement.

Allocation impact

With the introduction of the managed lane, the allocation of traffic between the managed lane and the other general traffic lanes will change and the speeds for each will change. These speeds and the travel times which result will depend on the allocation to each of the lanes and the speed flow curves for each type of capacity, which in turn will reflect how the different traffic streams interact.

The issues associated with the introduction of managed lanes on total travel times in the corridor may be compounded if there is a reduction in overall vehicle capacity along the route. Although traffic theory would suggest that the segregation of the carriageway would result in a loss of capacity, there has been practically no examination of the effects of introducing managed lanes on highway capacity, especially on arterial routes.

The opportunity was therefore taken to undertake a literature review and also use data for Onewa Road (North Shore City) to examine this position in more detail. The kerbside lane is designated as a T3 lane (cars with 3 or more occupants) in the morning peak. It is likely that there is a substantial volume of data that has been collected on the freeways and arterial roads which would allow the effects of introducing managed lanes on highway capacity to be examined, particularly from continuous traffic counts where this includes estimates of speeds. However, the only evidence that could be found where this had been analysed in detail was in San Francisco where two studies[1] had analysed the performance of the managed and general traffic lanes at a freeway location. The conclusion from this was that there was a loss of capacity of about 20 per cent in the HOV compared to the observed capacity of the other general traffic lanes.

Speed and volume data for Onewa Road in North Shore is collected by North Shore City Council, and count data covering much of the period from February to May 2009 was supplied to the consultants. This information is collected continuously in 15 minute periods, although a for speeds to be calculated a minimum traffic flow of 20 vehicles per 15 minutes is required. The data for both the managed lane and the general traffic lane was analysed separately for the periods when the managed lane was in operation and at other times of the day, and the results were examined to identify whether there was any systematic difference in the level of performance between the two periods. The data bases used to support this analysis were large giving confidence to the results obtained.

Graphs of the observed speed-flow relationships for the managed lane and general traffic lanes for the periods when the managed lane was in operation and at other times was analysed. The results of the comparison are displayed in Figures 1 and 2. Both graphs display significant differences between the performance of the two lanes with and without the operation of the managed lane, with the performance of the managed lane itself deteriorating by about 15 per cent (in terms of the speeds at a typical flow level, and that for the general traffic lane deteriorating by about 8-10 per cent.

While these impacts are slightly different to those observed in San Francisco, they illustrate the same general effects with the introduction of managed lanes resulting in an overall reduction in lane performance. This would suggest that whilst the person carrying capacity of the road may be improved with the introduction of a managed lane, it is likely to be at the expense of a deterioration in lane performance as the result of traffic in adjacent lanes travelling at different speeds and not being able to switch between lanes. This needs to be recognised in the development of the cases for these.

1 "What We've Learned About Highway Congestion," Pravin Varaiya (2005) *ACCESS*, Number 27 (www.uctc.net), Fall 2005, pp. 2-9 and "Effectiveness of High Occupancy Vehicle (HOV) Lanes in the San Francisco Bay Area" by Jaimyoung Kwon and Pravin Varaiya

Figure 1: Onewa Road Lane 1(The peak period Transit Lane)

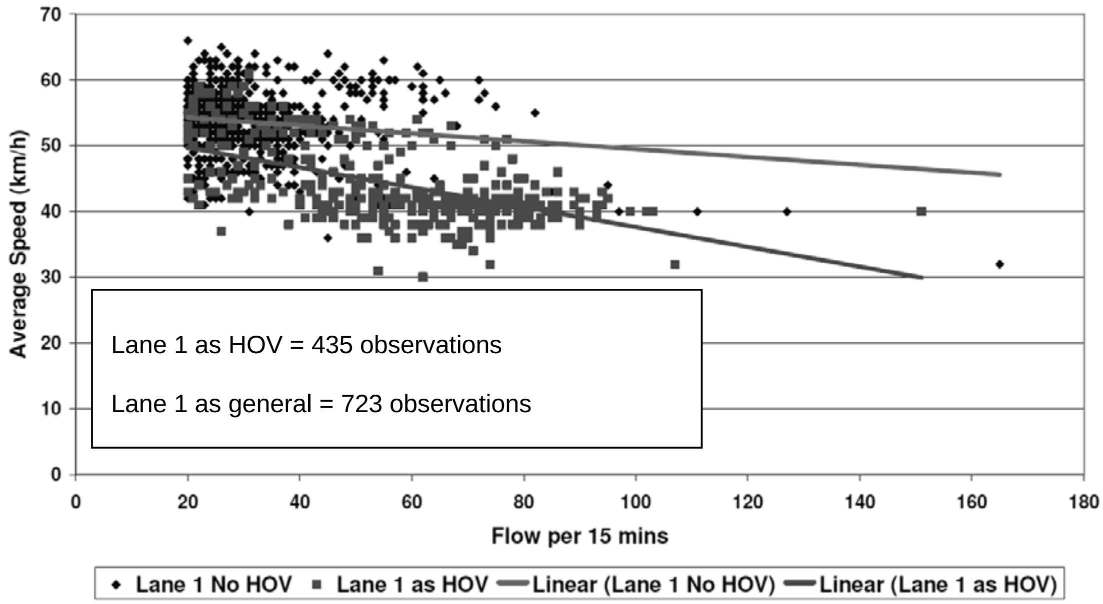
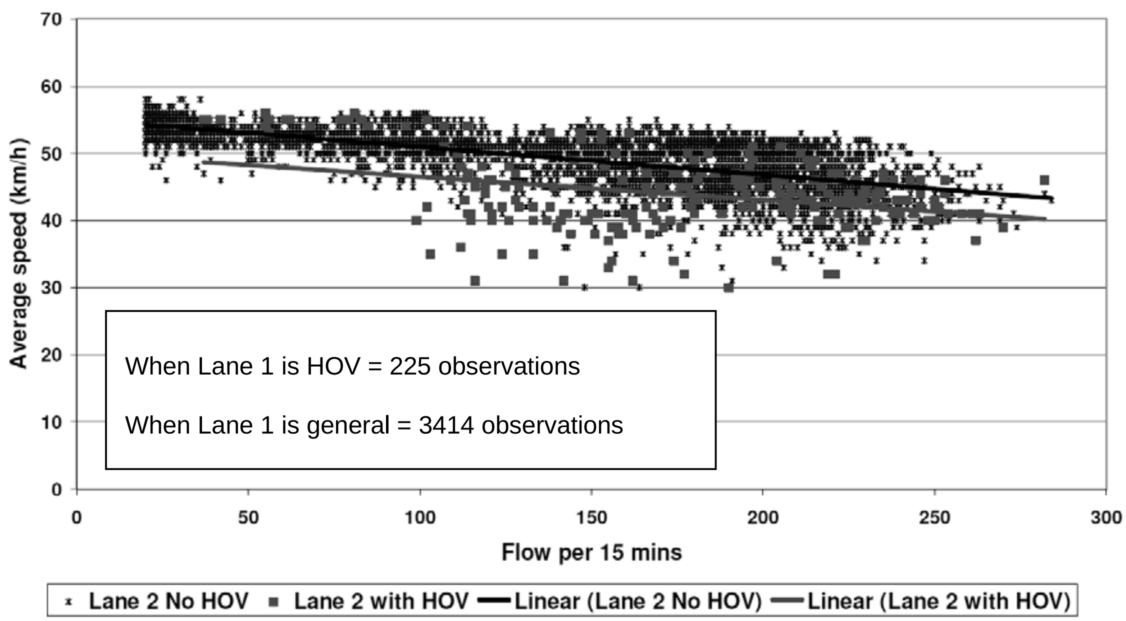
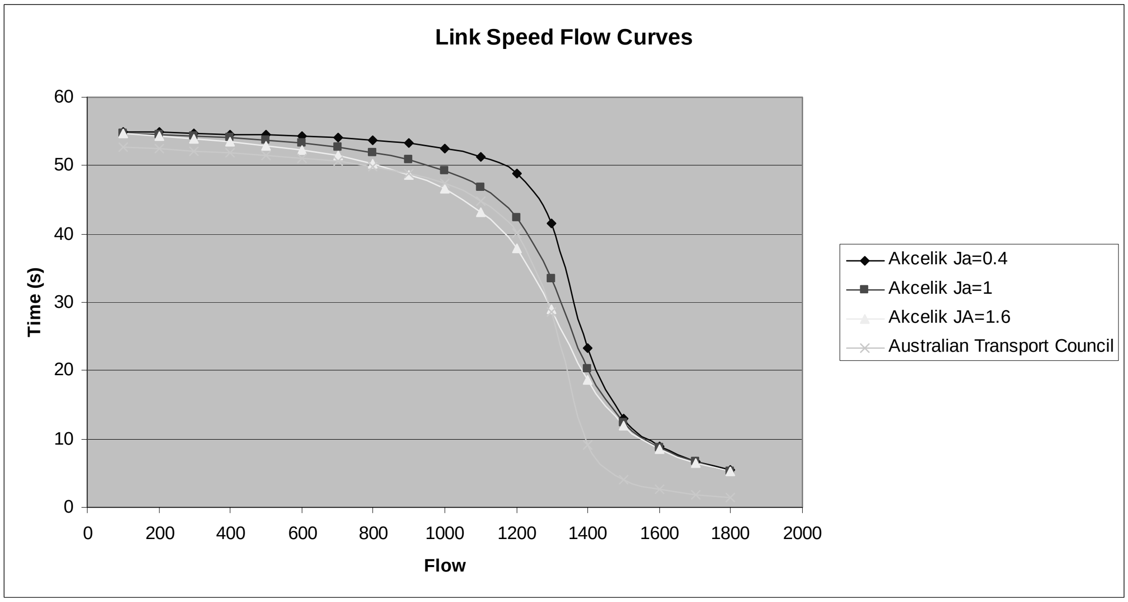


Figure 2: Onewa Road Lane 2 (The General Traffic Lane)



To simplify this in a model, and to give a reasonable, representation of the allocation effect, the Akcelik volume delay function was applied to determine what factors need to be modified in order to replicate midblock performance (refer to Figure 3). Adjusting the “friction factor” (Ja) provides a different slope producing a higher rate of decay for mid-block speed, whereas adjusting the free-flow speed changes would simulate the effects associated with differential lane speed (allocation effect).

Figure 3: Volume-delay functions for mid-block



Mode Shift and Longer Term Behavioural Impacts

Over the longer term there are likely to be behavioural impacts which improve the use of the managed lanes and their economic case. With the improved travel times in the managed lanes, users may be encouraged to switch from driving vehicles required to use the general traffic lanes to modes which take advantage of the improved travel conditions. This has the dual benefit of improving the split of traffic between the managed and other lanes, and also reducing the total volumes of traffic within the corridor, while keeping the numbers of people unchanged (assuming there is no shift from other routes within the corridor served).

While these changes are likely to occur, there have been no generally accepted guidelines on the extent to which this might happen, and the reported monitoring of this impact is very limited. The extent to which this will happen will be affected by two main factors:

- the extent to which journey times can be saved on the particular managed lane being investigated; and,

- the extent to which the managed lane proposed forms part of a comprehensive network from which passengers switching to HOV modes can benefit or where there are other measures put in place to support the operation of the managed lane.

As with all urban corridors, the primary source of delay is at the intersection, so it is logical to correlate the level of benefit of implementing an managed lane by ensuring that it continues through the intersections.

Impacts on Arterial Roads

Using the limited data available both from the monitoring on the Onewa Road transit lane [2] and some other results from overseas in the US[3], the UK[4] and Norway [5] the difference in

2 "North Shore City Council, Onewa Road Transit Lane, Review of Transit Lane Operation Following the Introduction of Enhanced Enforcement in August 2002" by David J Murray. 2003

journey time and the change in average vehicle occupancy has been determined for a small number of arterial road schemes and the results are set out in Table 2.

Table 2: Behavioural Response on Arterials : Vehicle Flows

Scheme	Country	Travel time saving (mins)	Type of lane	Increase in share of			
				T2s	T3s	T2s + T3s	Buses
Onewa Rd	NZ	20	T3	NA	120%	NA	15%
Vancouver	Canada	3	T2+	23%	12%	22%	NA
Snohomish	US	1	T2+	25-30%	Included in T2s	25-30%	NA
Leeds	UK	9	T2+	+5%	Included in T2s	5%	20%
Trondheim	Norway	1.5	T2+	+4%	Included in T2s	4%	NA

While the evidence is very limited, the provision of managed lanes on arterial routes appears to have raised the share of T2 and T3 traffic by a significant proportion. However, for the routes examined, there does not seem to be a particularly well-defined linkage between the level of time savings and the responses estimated by looking at changes in the shares by particular vehicle types. To some extent this reflects the position for Snohomish where employer incentives are reported as being provided and a slightly more consistent pattern emerges from consideration of the other three routes.

Impacts on Freeways

There is more information available on the reaction to the introduction of freeway based schemes, although again the data available is limited and the picture that emerges does not provide a clear and consistent link between the size of the potential time savings and the switch to higher occupancy modes.

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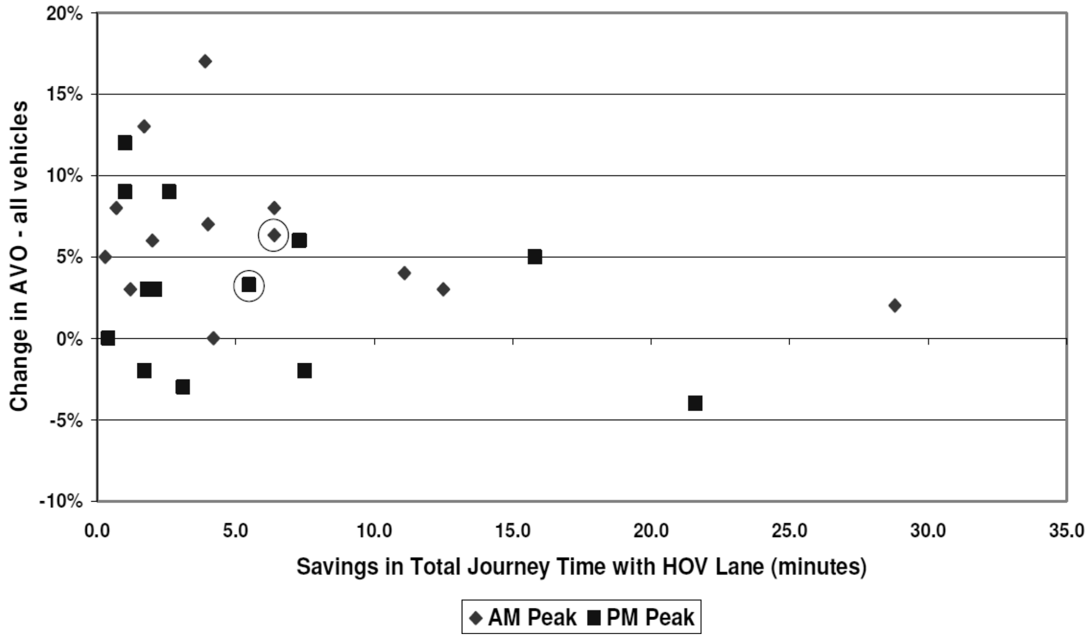
3 TRB "TCRP Report 95 :HOV Facilities : Traveller Response to Transportation System Changes",

4 "A647 High Occupancy Vehicle Lane (Opened 11th May 1998)" Factsheet prepared by Leeds City Council January 2007,

5 "Reallocation Road Space:Introducing HOV-Lane in City of Trondheim" by Snorre Laegran, Norwegian Public Roads Administration, November 2001

Figure 4: Freeways in Los Angeles County : Changes in Total Travel Times and Changes in AVO with introduction of HOV Lanes



The data does however suggest that while the determination of the exact details of the relationship is not easy, the introduction of managed lanes on freeways has typically resulted in increases in the average vehicle occupancy (AVO). This is illustrated by examining the position for the freeways in Los Angeles County in about 2000 as set out in Figure 3. The average positions for the AM and PM peak are highlighted.

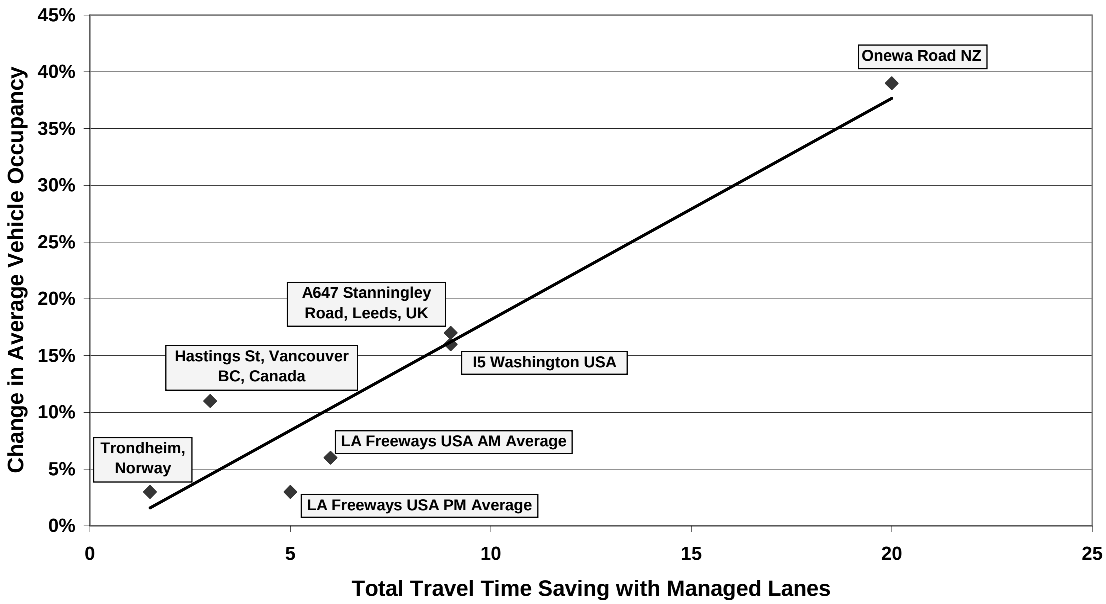
For the AM peak the introduction of HOV lanes appears to have resulted in increases in average vehicle occupancy for almost all the schemes examined. For the PM peak the position is more mixed with some reductions, although this may possibly reflect different commuting patterns and greater variability in the departure times from work or other activities undertaken.

Overall Assessment

It is possible to put together the results obtained from the various sources discussed above in a single summary figure and the position that results is set out in Figure 4. Figure 4 excludes the results for Snohomish County because of the particular characteristics of this scheme.

By pooling the data, the position that results is of a fairly strong relationship between travel time savings and modal response, although it should be recognised that this is subject to a considerable degree of uncertainty when applied to particular schemes and proposals. However in the context of planning for managed lanes the relationship defined does provide an initial baseline for their assessment, although wherever possible the particular characteristics of the scheme should be assessed to determine whether these are likely to be sufficient to change the response that might be achieved.

Figure 5: Relationship between Average Vehicle Occupancy and Travel Time Saving



Given the importance of this response in determining whether managed lanes are likely to be successful, it is desirable that the existing very limited database be supplemented by further detailed data collection from schemes that are currently being implemented.

MODEL DEVELOPMENT

A simple spreadsheet model has been developed to assess the relative performance of managed lanes on arterial roads, accounting for the major inflential factors in urban corridors namely:

- Intersection performance
- On line or off line bus stops and bus stopping times
- Bus stopping times
- Level of take-up and level of violation.
- Intersection spacing and level of co-ordination
- Parking
- Merging/Access

The model calculates the estimated travel times along the corridor for different classes of vehicles, and then converts that into person travel times for assessment against the performance measures.

The model architecture is presented in Figure 6 and includes three main inputs:

- Geometric (layouts and green time proportion)

- Traffic Parameters (traffic volumes, proportion of HCV's and vehicle occupancy, level of behavioural response)

- Bus infrastructure (number and location of bus stops, passenger demand, indented bays)

The model results are presented as a series of tables and figures showing the relative performance of the different types of managed lanes based on the above inputs. The performance measures selected are those outlined earlier in this paper.

The advantages of the spreadsheet model are:

- It is generic and can be applied across New Zealand.

- Provides results for different performance measures and not just vehicle travel times.

- Provides graphical outputs to show the effect of the managed lanes over time.

- Uses established analytical techniques outlined in the Highway Capacity Manual (Urban Streets, and signalised intersections).

- Includes link delay (which HCM does not) due to potential link capacity constraints associated with demand exceeding capacity in general lane/s (uses the Akcelik volume delay functions for estimating link delay).

- Uses establied methods for bus journey times outlined in the Transit Quality and Services Manual.

- Allows for a route with a consistent cross section to be examined.

- Allows for an "elasticity" to be applied, if forecast mode splits and vehicle occupancies are not known. The elasticity used has been derived from the research work presented earlier in this paper.

- Is flexible enough so that it can be set-up without knowing turning counts, although the degree of confidence will be reduced.

- The model allows for the impact of buses and bus stops in the kerbside lane.

The current limitations of the model are:

- The model does not include allowances for lane changing due to lane blockage either mid-block (e.g. bus stops), or where there the combination of left turn traffic and HOV traffic in a kerbside lane are greater than the lane flow in other lanes at the intersections

- The model does not yet allow the user to specify the lane utilisation for a kerbside lane where a through movement is permitted or where there is a downstream merge. This is currently being incorporated.

- The model does not yet allow for the bottleneck delay associated where the general traffic lanes merge.

- The model applies only to signalised intersections.

- Only a single elasticity is considered – different short term and long term elasticities are not considered where forecast vehicle and passenger numbers are not known.

- There is a limitation on the capacity of the right lane where filtering may be permitted or where it is allocated as a through-right movement.

MODEL TESTING

The spreadsheet model has tested against the TRANSYT modelling conducted for the Albany Highway upgrade, and provided very good correlation with the predicted vehicle speeds calculated by the TRANSYT models for the future years. This provided a good indication that the model would provide a similar level fo confidence to traditional traffic models.

Figure 6: Model development process

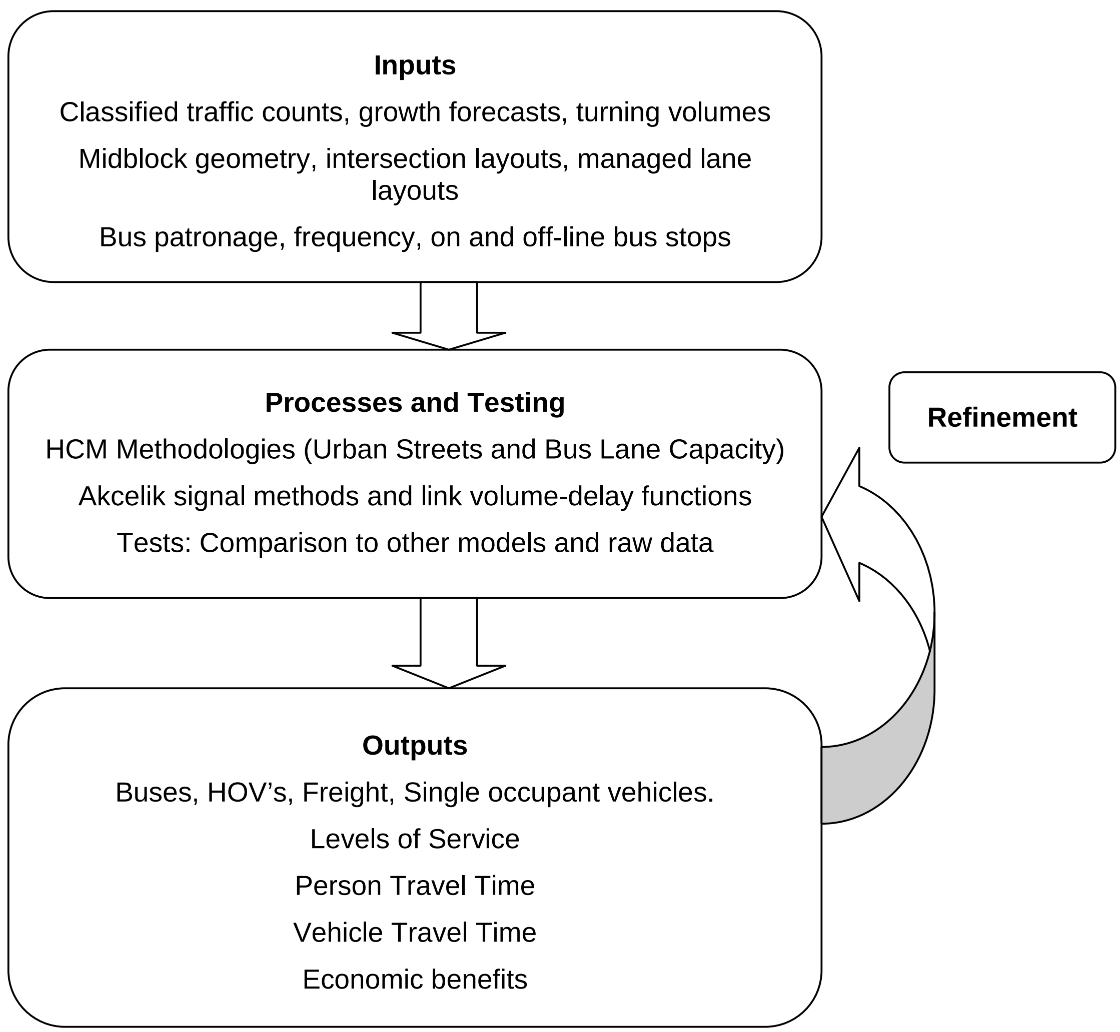


Figure 7: Example of outputs of person travel time for Albany Highway

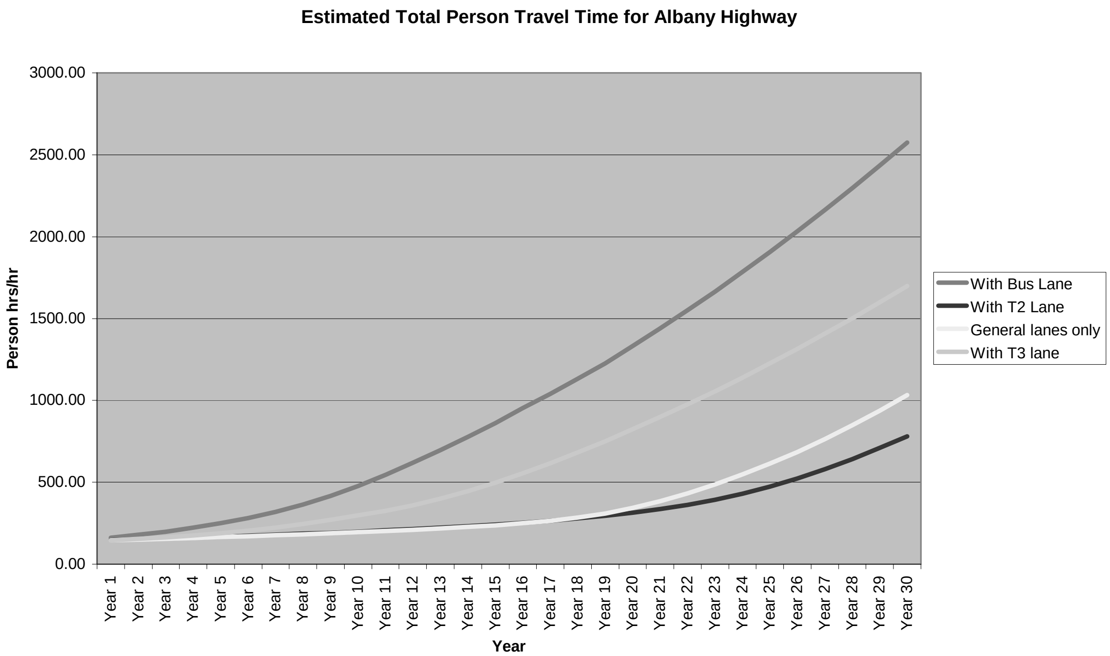
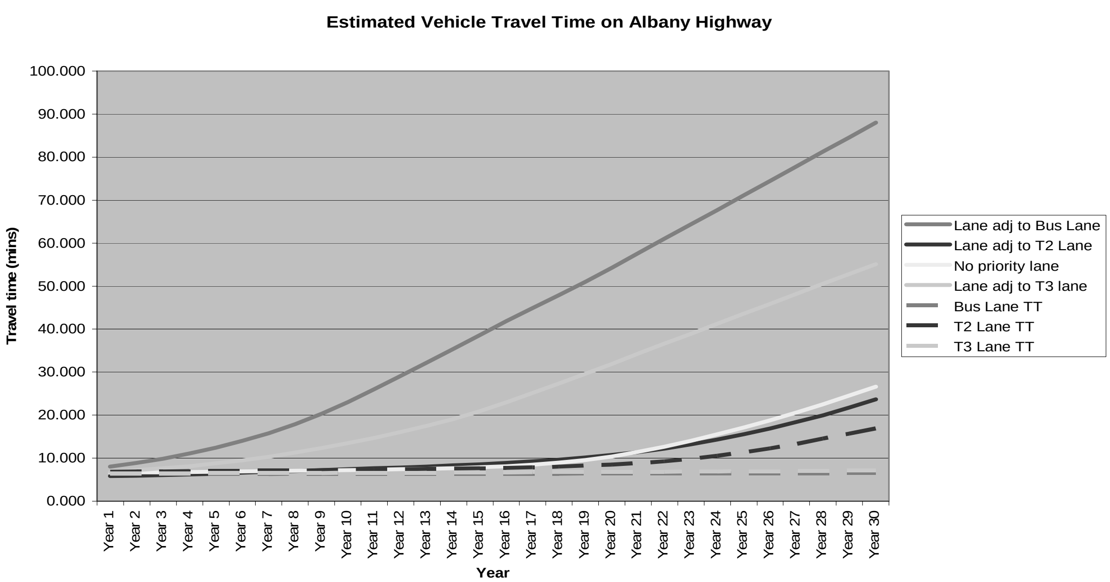


Figure 8: Example of outputs of vehicle travel time for Albany Highway



The outputs in Figure 7 and Figure 8 are were used for comparing it against the TRANSYT outputs but without consideration of elasticities. The estimated travel times were within approximately 10% of the results predicted in TRANSYT (although green time is an input into the spreadsheet model). The example of Albany Highway indicates that the estimated person delay with a T2 lane (without consideration of elasticities) would be a similar to that of general traffic lanes, but also better reliability of journey time for buses.

When the elasticities were applied, it was found that if the calculated increase in traffic eligible to use the HOV lane resulted in a longer travel time for that lane, then the model would not converge. Logically the modelled increase in eligible vehicles in the priority lane should be limited to the traffic flow that would generate a travel time equal to the general traffic lanes (i.e. the ultimate convergence of the elasticity model). The model algorithms are currently being updated to reflect this.

FINDINGS AND CONCLUSIONS

The introduction of managed lanes has both a short-term allocative impact and a longer term behavioural response. The former is in many cases adverse, with a less well balanced allocation of traffic in the capacity available, and even with the use of the managed lanes by higher value vehicles, overall travel times in the corridor for all users are likely to increase. Over the longer term, the second effect, the behavioural response to the changes in travel times is likely to be positive, reducing the total volume of traffic in the corridor in relation to the numbers traveller and achieving a better balance between the use of the managed and general traffic lanes.

The spreadsheet models developed take the behavioural response and lane interaction impacts into account when predicting the performance of the managed lanes. The models have been used to assess the potential of implementing managed lanes along a number of arterial corridors within the Auckland Region including:

- Remuera Road
- Manukau Road
- Albany Highway

Typically, what has been found is that the overall vehicle travel time is expected to increase, the overall person delay has the potential to decrease along the corridor, regardless of which type of managed lane is implemented provided that the number of people being transported in the managed lane of the lane is at least greater than the number of persons in the general traffic lanes As expected though, the bus lanes provide the greatest reliability for buses, with the T2 lanes providing better overall person delay times.

The spreadsheet model provides a simple and useful tool to assess the predicted performance of a managed lanes and provides a quantifiable estimate of performance, rather than relying on a policy decision for selecting whether a managed lane is desired, and what that should allow.

Further investigation is needed into:

- The allocation effect through observation of established managed lanes on arterial roads.
- The short and long term behavioural responses (including changes in bus patronage)

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