Balancing the Economics of Passing Lanes

Bevan Wilmshurst (Presenter)

Principal Transportation Planner, Traffic Design Group

BSc, BMus

Member IPENZ Transport Group, NZMUGs Committee Member

bevan.wilmshurst@tdg.co.nz

Bevan is a Principal Transport Planner with Traffic Design Group. Significant experience and a keen interest in Planning and Scheme Appraisal in New Zealand and in the UK over the past 12 years has guided Bevan towards leading and consolidating innovative and modern assessment techniques. This is based on a strong foundation in delivering to the highest quality projects such as design investigations, economic evaluations of roading schemes, public transport projects, and infrastructure and development management studies.

Peter Kirby

Principal ITS Engineer, Traffic Design Group

BEng (Hons), CEng (UK) MIET

Member Institution of Engineering and Technology

peter.kirby@tdg.co.nz

Peter is a Principal ITS Engineer with Traffic Design Group with 11 years' experience in the design, implementation, operation and evaluation of traffic control systems for local and national government agencies in the UK and NZ. Having undertaken key roles in the UK's ramp metering implementation projects and the detailed design of the M62 J25-J30 Managed Motorway scheme, Peter is well versed on motorway control systems and traffic behaviours.

INTRODUCTION

New Zealand's topography and distance between major urban centres creates some unique considerations for our road network. The rural 2-lane State Highway network is a key component - linking urban areas, tourist destinations, playing a key role in the movement of freight, and carrying 30% of New Zealand's total annual road travel (vehicle kms travelled). Currently the large proportion of this network (around 73% in terms of length) carries lower traffic volumes. In the future a much higher proportion of the network will carry moderate to higher volumes, 5,000 to 25,000 AADT. It is also anticipated that the proportion of slow vehicles, e.g. freight, will increase as the economy grows.

The combination of geographic constraints, increasing flow, and increasing proportion of slower commercial vehicles places greater emphasis on the suitability and performance of passing facility treatments. At higher volumes, passing lanes are generally not treated as isolated facilities, they are considered as a route/corridor treatment with a number of passing lanes placed in series.

THE ECONOMICS

Economic analysis is one method used to investigate the merits of a transport intervention. This framework balances the cost of the intervention against the benefits it offers road users and the wider economy. The installation of a passing lane facility is accepted to generate four sources of benefits (NZTA 2010);

1. Reductions in travel time due to faster journeys after overtaking slower vehicles
2. Reductions in driver frustration from less time spent following slower vehicles
3. Changes in Vehicle Operating Costs due to faster speeds (typically a slight dis-benefit)
4. Reductions in crashes due to safer overtaking opportunities, i.e. lack of 'risky' overtaking

As vehicles travel from A to B along a route, their experience of the conditions of the road network varies and is influenced by the characteristics of the traffic flow, network features, and environment. In the case of passing lanes, Vehicle Operating Cost (VOC) differences are typically a minimal dis-benefit due to higher speeds. Safety benefits are more significant, the profile of benefits along a route treated with a series of passing lanes is relatively straightforward and this is discussed later. The focus of this particular paper is on efficiency benefits, how these are affected by passing lane lengths and spacings, and how they can be measured.

How the efficiency benefits (reductions in travel time and driver frustration) accrue along the route from A to B is reasonably complex;

- Without the passing lane, the performance of the route would deteriorate over long distances as slower vehicles control the speed of large platoons containing frustrated drivers with desires to travel above that speed.
- With the passing lane in place, a proportion of faster vehicles are able to pass slower vehicles and enjoy a certain distance of unimpeded travel. Not all vehicles carry out passing manoeuvres, and some vehicles which do pass may catch up to another slow vehicle or platoon more immediately downstream of the passing lane.

Figure 1 shows a simplified representation of the profile of the corridor performance and savings along a longer route. The graph on the left shows the potential difference in the performance of the route with and without a passing lane, and the graph on the right demonstrates how this may be translated into efficiency savings (benefits).

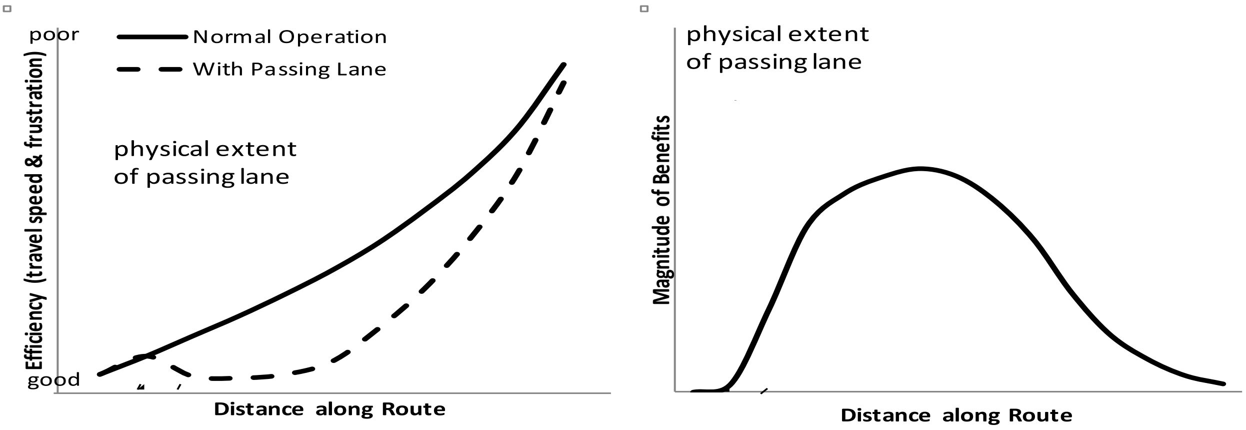


Figure 1: Passing Lane Efficiency Savings

An important aspect of these relationships, as noted by Clement and Druitt (2006) is that the main efficiency benefit of an overtaking scheme is not just felt in the area where the improvement is undertaken, but for many kilometres downstream.

THE PROBLEM

As with all transport improvement projects, there is a need to ensure money is well spent, i.e. that infrastructure designs are fully optimised and that economic benefits are robustly measured. TVNZ (2012) reported recent failures to fully deliver on the anticipated economic benefits of transport schemes, quoting passing lanes as particular examples. Passing lane schemes, may fail to delivery optimal benefits as a result of one or more of the following characteristics:

1. An 'ambitious' / overly optimistic economic evaluation
2. Length of the passing lane is not optimal, e.g. not long enough to enable a sufficient quantity of faster vehicles to pass, or too long resulting in the majority of passing manoeuvres being completed in the initial length and an underutilised end section
3. Passing lane positioned in a location where traffic demand, network topography and characteristics mean that vehicles are not sufficiently 'platooned' before the passing lane to enable optimal passing of slower vehicles
4. Insufficient downstream section of carriageway over which to realise the benefits.

The interactions described in relation to Figure 1 are reasonably complex, however the apparent solution would seem to be to space the passing lanes at the location where the magnitude of benefits exist (the peak on the graph on the right). These graphs only show the journey time and frustrations savings, **this does not account for the cost** of the passing facilities along the route and is therefore unlikely to be the optimal economic solution.

So the question is: How long should passing lanes be and what spacing between adjacent passing lanes along a route is required to maximise the return on investment?

ASSESSMENT TOOLS

How do we account for these complex interactions and determine the optimal economic placement of passing lane facilities along a route? To measure the economic returns of a transport intervention we need to stare into our crystal balls and predict how the road network will perform with the intervention in place, and commonly, how it will perform in the future with changes to travel demand (e.g. traffic growth). This is generally done using transport models and broadly there are two types of transport models;

- Macroscopic models (also known by various terms including deterministic, strategic, and regional), so called because they deal with aggregate traffic flows e.g. hourly flows on a link, at an intersection, or across a network. SIDRA and SATURN are common examples in New Zealand.
- Microsimulation models, so called because they model individual vehicles in small time increments (commonly less than 1 second). Paramics, VISSIM, and AIMSUN[1] are common examples in New Zealand.

To assess the optimal arrangement of passing lanes along a route we ideally need a tool which will predict the complex interactions which vehicles will experience on their journeys – notably how platoons will form and disperse along the route, and how vehicles will utilise passing and overtaking opportunities. By modelling these predictions, we are able to record the efficiency savings (reduction in travel time and driver frustration) and measure the benefits of the scheme.

Aggregate transport models (macroscopic) struggle to *predict* how these interactions will vary as the characteristics of the network change. They rely on empirical relationships between flow and theoretical capacity. Generally the parameters which describe the road network and traffic characteristics are uniquely defined, which means these forms of models are effective for certain assessments but have limited capacity to accommodate effects which have not been anticipated and previously measured. E.g. a queue from one intersection blocking an adjacent intersection.

Microsimulation is better suited in these situations, the simulation of individual vehicles' journeys through the network combined with the representation of varying driver and vehicle characteristics (distributions) provides a robust platform for measuring the interactions of traffic flow and roading features, e.g. passing lanes in series along a route.

MODELLING OF PASSING LANES

Microsimulation modelling aims to mimic on-street driver behaviour. As an example, a vehicle in the model following another vehicle and performing a passing manoeuvre in a passing lane will;

- Decide if they wish to travel faster than the vehicle ahead
- If they do, move into central lane and accelerate to pass the slower vehicle
- Then look for a gap in the traffic flow to merge back into the kerbside lane

The urgency to move back into the kerbside lane increases as the vehicle approaches the merge at the end of the passing lane.

Increasing the length of the passing lane will naturally provide vehicles with a greater opportunity to stay in the central lane (the passing lane) for longer and will therefore intrinsically predict increases in passing manoeuvres. With the established distributions of driver behaviours and traffic characteristics represented in microsimulation, these models are designed to generate these outputs naturally (e.g. increased passing lane use) - no parameters need to be adjusted or factored. The model also employs the same robustness to the predictions of other critical aspects, notably the formation and dispersion of platoons. Microsimulation is not only better suited to assessing the economics of passing lane facilities – it's the only tool that has the flexibility and function to measure the complex interactions between adjacent passing lane facilities.

[1] Historically the simulation package TRARR has been used for research and investigation into passing lane facilities in New Zealand and Australia. The development and capabilities of this model may be limited compared to the commercially developed software listed above, Koorey (2003) noted a number of existing concerns and limitations have been identified with this package, and no further upgrading is planned. In any respect, site-specific (or research based) modelling should be calibrated to represent the existing on-street operation (Do Minimum) to a suitable level and capable of predicting the behaviours associated with the scheme being investigated. E.g. in the case of passing lanes, the key aspects being the dynamics of vehicles (speed distribution, acceleration etc) and representation of passing manoeuvres through the facility, resulting in the travel time savings through the study area and changes to platooning.

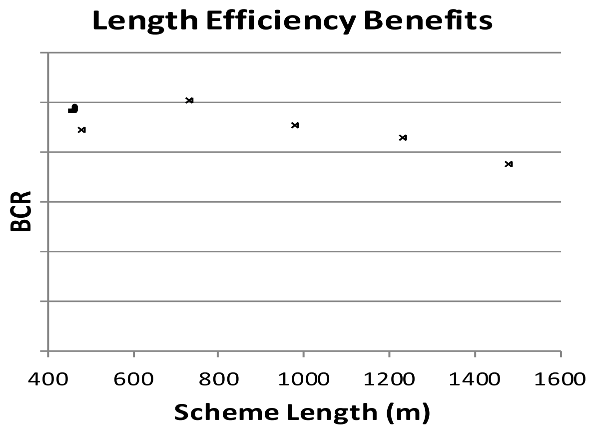
The value of microsimulation has been recognised in the UK where it is mandatory for the economic assessment of 2+1 treatments, a series of alternating passing lanes along a route. The Design Manual for Roads and Bridges (2008) states that traditional traffic assignment models, which are often referred to as “macroscopic”, cannot model the formation and dispersal of vehicle platoons essential for the economic assessment of a 2+1 road. In order to provide a realistic and robust economic assessment of the benefits of a 2+1 road, traffic modelling must be undertaken using microsimulation.

INVESTIGATING OPTIMAL LAYOUTS

In NZ, microsimulation modelling has been used to undertake a detailed investigation into the economic relationships for passing lanes in series at AADTs between 5,000 and 25,000 as part of on-going research conducted by the Authors. This involved calibrating traffic models to a range of existing on-street sites featuring passing lanes in different environments (e.g. varying terrain and volumes, passing lane utilisation). In each case, the sites were calibrated using the same (generic) parameters; physical vehicle dynamics, heavy vehicle gradient responses, speed, headway, passing lane end warning distance, and timestep (simulation recalculation interval).

The inputs to the model (i.e. the factors that can be varied / investigated) include the length and vertical/horizontal geometry of the study area, traffic demand, heavy vehicle percentage, levels of overtaking in the face of on-coming traffic, and the length and location of passing lanes. All of these inputs will naturally result in varying predictions of platooning levels and journey times through the study area, i.e. the outputs which form the basis of economic saving calculations.

Initially the modelling investigated the basic journey time savings of passing lane facilities compared to a Do Minimum scenario without any passing lanes. The results were correlated with the cost of the facilities (at a fixed rate per km of passing lane) to produce efficiency BCRs. Figure 2 shows the efficiency benefits for 10,000 AADT. The graph on the left shows a test with a single passing lane of varying passing lane lengths. The graph on the right shows results from a fixed passing lane length scenario, with varying spacings between adjacent passing lanes.



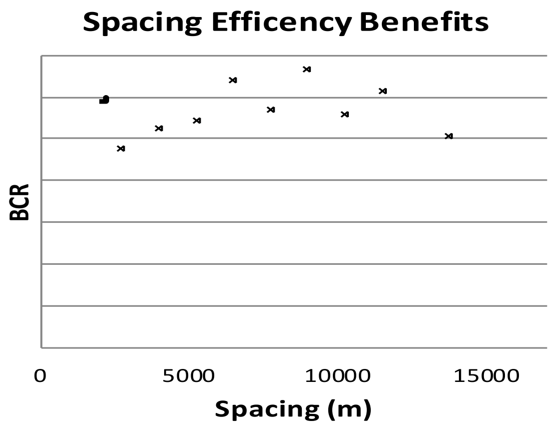


Figure 2: Passing Lane Length and Spacing Efficiency Examples

The graphs above show broadly how the economic relationship between savings and cost varies for passing lane length and the spacings. For passing lane length, the graph on the left shows a relatively steep rise as utilisation increases more quickly from short passing lanes (500m) to more moderate lengths (800 – 1000m). The return from longer passing lane diminishes gradually. For passing lane spacing, the relationship is more sensitive and evenly distributed across the range of spacings in this test. These graphs are one example, the magnitude of benefits and optimal BCR point varies for different AADT, heavy vehicle percentage, terrain etc.

OPTIMAL ECONOMIC EFFICIENCY

Accidents, frustration, and vehicle operating costs need to be considered to form a complete picture of the optimal economic balance in locating passing lanes in series through a rural State Highway route. The EEM NZTA (2010) passing lane accident saving method assumes that the typical New Zealand rural 2-lane crash rate reduces over the length of the passing lane. This reduction in crash rate then declines linearly downstream of the passing lane until the typical rate is reached. From this assumption, the crash rate savings can be calculated from the passing lane length and spacing layouts. Frustration benefits accrue due to reduced levels of vehicle platooning. This benefit is related to all vehicles that are freed from a platoon at the passing lane, and is applied over the distance they travel where they are no longer following another vehicle. This measure was calculated from sampling the headway (which determines whether a vehicle is in a platoon) at points through the study area. Vehicle operating costs can be calculated from the average speed of vehicles through the study area. An increase in average speed results in a minor dis-benefit in vehicle operating costs.

Compiling the full set of economic outputs allows the optimal combined passing lane length and spacing arrangement, or 'sweet spot', to be estimated. From the Authors' on-going research, a draft example of how this can be presented is shown in Figure 3 for AADT 10,000 and 15,000. Note the difference in scale on the x (distance access) to highlight the 'sweet spot'

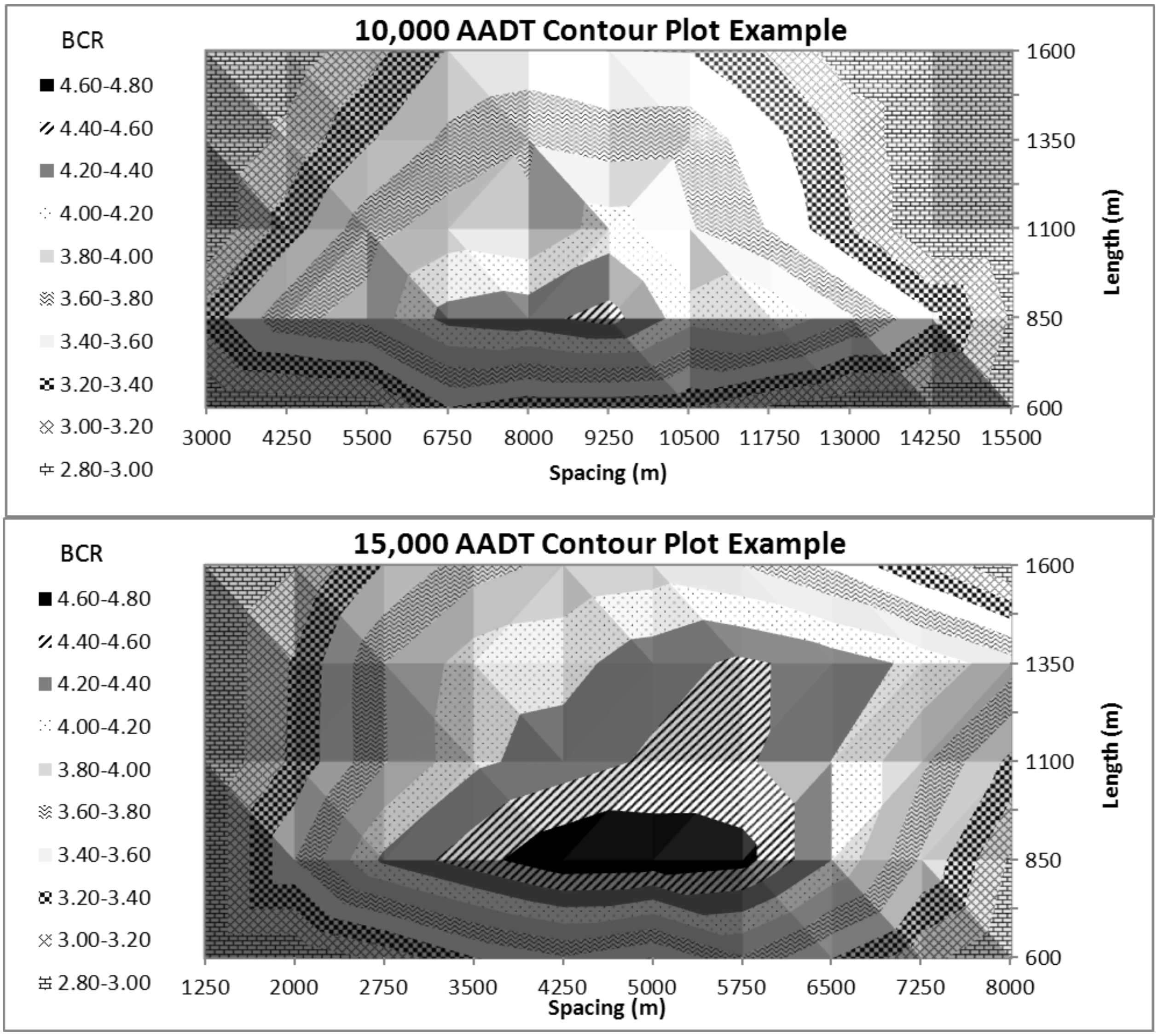


Figure 3: Optimal Passing Lane Length and Spacing

For these particular configurations (AADTs, terrain, %HCV and traffic growth forecasts, passing lane construction costs) shown in Figure 3 above, the influence of the difference in flow on the magnitude of benefits (higher maximum BCR at larger AADT) and optimal length and spacing can be recognised (shift in optimal spacing from around 9km at 10,000AADT to around 5km at 15,000AADT, and longer passing lane lengths at 15,000 AADT. (Note the difference in x axis scale so the sweet spot is easily identifiable).

CONCLUSIONS

NZ's 2-lane rural State Highway network will continue to play an important role to support the economy, carrying higher traffic volumes and an increasing proportion of freight in the future. Increasingly, passing lanes will need to be considered as a route treatment, i.e. as a series of adjacent, interactive, facilities rather than individual schemes.

In order to provide the best value-for-money, the interaction between adjacent facilities needs to be considered robustly and the resulting efficiency savings balanced against the cost of implementing schemes. The economically optimal solution considers the passing lane length, the spacing between passing lanes, and the placement of the facilities on the local route. These elements are influenced by the traffic characteristics - AADT, terrain, percent heavy vehicles, and traffic growth. This can all be determined using robust microsimulation modelling.

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REFERENCES

Manual

DESIGN MANUAL for ROADS and BRIDGES (2008), volume 6, section 1, part 4. Design of Wide Single 2+1 Roads.

NZTA (2010), Economic Evaluation Manual, Volume 1, NZ Transport Agency.

Journal

CLEMENT I and DRUITT S (2006). Economic appraisal by microsimulation. *Traffic Engineering and Control*

Research Report

KOOREY G (2003), Assessment of Rural Road Simulation Modelling Tools, *Transfund New Zealand Research Report No. 245*

Internet

TVNZ (2012), Audit shows transport projects 'should not have been funded. http://tvnz.co.nz/national-news/audit-shows-transport-projects-should-not-have-been-funded-5298832

ACKNOWLEDGEMENTS

Dr Glen Koorey, University of Canterbury.