Through-lane Use at Traffic Signals

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Abbreviations and Acronyms

ARR:	Australian Road Research
AUSTROADS:	National Association of Road Transport & Traffic Authorities in Australia
B/C:	Benefit/Cost
CAS:	Crash Analysis System
FYRR:	First Year Rate of Return
GIS:	Geographical Information System
HCV:	Heavy Commercial Vehicle
LTNZ:	Land Transport New Zealand
m/s:	metres per second
SCATS:	Sydney Co-ordinated Adaptive Traffic System
SEART:	Southeastern Arterial

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Executive summary

Introduction and objectives

This research was carried out between July 2004 and December 2005. Its aim was to determine the scale of effect of having short[1] through-lanes on approaches and short downstream merges on through-lane use[2] at signalised intersections, and to find ways of improving this use. This involved surveying and modelling three signalised intersections in Auckland. The main conclusions reached are listed below.

Short through-lane utilisation – survey results

Traffic surveys were undertaken at the signalised Sandringham/Balmoral and Mt Eden/ Balmoral intersections for the purpose of comparing lane use on the Balmoral Road through-lanes on both intersections, with the following results:

- At the Balmoral/Mt Eden intersection during the morning and evening peaks and the off-peak period, the short through-lanes (on the left) on Balmoral Road were used less on average (11.5%) than the adjacent through-lanes on the middle (40.5%) and right (48%). Also, the rate of use of the short through-lanes was lower when the intersection was less busy, with an average of 8.5% during the off-peak and an average of 12.5% during the a.m. and p.m. peaks.
- At the Sandringham/Balmoral intersection, the longer 'short' lanes had a higher rate of use (16.5%) than that of the reduced length 'short' lanes at the Mt Eden/Balmoral intersection (11.5%). If the Sandringham/Balmoral intersection's rate of use was adjusted by the effects of greater congestion, it would probably have been around 20%.

Consequently, the conclusion was that in general, short slip lanes and short approach and departure through-lanes cause short through-lanes to be used less.

Short through-lane length versus lane use

A preliminary comparison was made between the lengths and lane use of short slip lanes and short through-lanes. A direct correlation was identified. Also, short lane use was substantially less than that expected by a typical traffic model for the same lane length. Furthermore, the graphs indicated that approach lane length and departure lane length had a similar effect on lane use.

However, the data source was limited and the results not significant. Useful technical data could be obtained by undertaking a detailed study comparing the lengths of short through-lanes upstream and downstream, and surveying their associated rates of use. If the database was extensive enough to achieve statistical significance, then the results would enable engineers to predict the expected rate of use for proposed short lanes at intersections accurately. This information could be used during traffic model calibration, enabling improved design and greater accuracy in modelling and economic analysis.

Lengthening short through-lanes – economic analysis

An economic analysis was undertaken to determine the benefit/cost value of lengthening the Balmoral Road short lanes at its intersection with Sandringham Road. It was determined that by lengthening the sum of the approach and departure lengths of the Balmoral short lanes at the Balmoral/Sandringham intersection (so that the westbound lanes totalled 175 m and the eastbound totalled 100 m), a 25-year benefit of around $3 million would be created. At a construction cost of $627,000, this would generate a benefit/cost value of 4.9, indicating that the project was beneficial economically. Also, the cost of the additional works is relatively small in comparison to the overall cost of the original upgrade (around $7 million).

Alternative short lane arrangements

Traffic surveys were undertaken at the signalised intersection of the Southeastern Arterial (SEART) and Carbine Road for the purpose of reviewing how the three westbound through-lanes on SEART were used, including a 'lengthy' short through-lane located on the right for both approach and departure. The results indicated that the three through-lanes were used evenly, which was attributed to the length of the through-lane, the lane being on the right and the predominant downstream destination being the motorway, which is on the right. It was concluded that use of short approach and departure through-lanes may be enhanced by lengthening the short lanes and by placing the short lanes on the right with a suitable downstream destination.

A right-side merge had some unwanted effects on non-injury accident statistics, but further crash analysis would be required to determine the significance of the problem. If crash statistics were an issue, accident remedial measures, such as enhanced signage or road-marking delineation, could mitigate the problem.

As a result of this research, two low-cost alternative short lane configurations were identified to improve short lane use, being (i) a short approach and short departure on the right and (ii) a short approach on the right and a short departure on the left. These alternative short lane configurations could be investigated further, possibly with a trial to evaluate the costs and benefits.

Proposed upgrade of the Balmoral/Mt Eden intersection

If the economic analysis undertaken at the Sandringham/Balmoral intersection were to be applied to a proposal to lengthen the Balmoral Road short lanes at the Balmoral/Mt Eden intersection, then a similar benefit/cost result would be achieved. However, this analysis was approximate and further investigation would be required to confirm the result.

Also, two alternative lane arrangements were suggested for improving lane use and operational efficiency along Balmoral Road at its intersection with Mt Eden Road. Only road-marking changes are required, with no road widening. Further investigation would be required before implementing such proposals, including a review of downstream destinations and merge capacity.

Short lanes in New Zealand

Ten signalised intersections have been identified in Auckland that could benefit from having their approach and departure lanes lengthened. Based on the economic results obtained from the analysis undertaken at the Sandringham/Balmoral intersection, it is likely that the proposed works would be economically viable, but this would need to be investigated further. Many more intersections in cities throughout New Zealand could benefit from similar works.

Preliminary guide for predicting and improving short lane use

The key finding from the research is that short through-lanes on approach and departure are used less than adjacent full-length lanes. Consequently, lengthening such lanes would increase their rate of use and thus make the intersection operate more efficiently. Guidelines have been drawn up to assist practitioners when designing short through-lanes at signalised intersections.

Recommendations

- This research report should be distributed to all road controlling authorities to increase general awareness regarding the low rate of use of short through-lanes at intersections.
- Further investigation should be done to create a technical database comparing the lengths of slip lanes and short upstream and downstream lanes and surveying their use. A statistically significant database would enable engineers to predict the expected use of proposed short lanes at intersections accurately, which could be used for traffic model calibration. This would improve analysis and design and greater accuracy in modelling and economic assessment.
- An investigation and trial should be conducted to evaluate the costs and benefits of short approaches on the right and merges at intersections as an alternative short through-lane configuration.
- Councils throughout New Zealand should consider lengthening short through-lanes at congested intersections. At the Sandringham Road/ Balmoral Road intersection, the theoretical short lane lengthening created a 25-year saving of around $3 million. If the proposed works at the ten identified intersections were to be implemented, then a financial saving of around $30 million could be created.

1. **Short lane:** The term 'short lane' used throughout the text indicates an auxiliary through-lane which is shorter than adjacent through-lanes.

2. **Through-lane use:** For any through-lane of a traffic signal approach, the through-lane use is defined as the percentage of all through-traffic on that approach using that lane. For example, for two, three and four through-lane approaches, the target rate of use for the individual lanes would be 50%, 33% and 25%, respectively.

Abstract

Research was undertaken during 2004/05 to determine the effect of short approach through-lanes and downstream merges on lane use at signalised intersections, and to find ways of improving use. This involved surveying three intersections.

In general, short slip lanes and short approach and departure through-lanes cause short through-lanes to be used less. Accordingly, a guide was prepared to provide preliminary information to assist practitioners to predict and improve short through-lane use.

A direct correlation was identified between short through-lane length and associated lane use. Also, short lane use was substantially less than that estimated by an analytical traffic model. Furthermore, graphs indicated that approach lane length and departure lane length had a similar effect on lane use.

Economic analysis demonstrated that lengthening short through-lanes was economically viable.

Analysis of a short lane on the right showed that it was more likely to be evenly used than a typical short lane on the left.

Three alternative short lane configurations were identified which may improve short lane use, involving approaches and/or merges on the right.

Ten signalised intersections were identified that could benefit from lengthening short lanes.

1. Introduction

1.1 Project brief

The research brief for this project, carried out between August 2004 and September 2005, was to determine the effect of short approach lanes and short downstream merges on through-lane use at three signalised intersections. This involved undertaking traffic counts and queue surveys, and analytical traffic modelling.

The analysis was designed to produce results that could be applied to other signalised intersections in Auckland and New Zealand to make them operate more efficiently.

1.2 Definitions

1.2.1 Short lane

The term 'short lane' used throughout the text indicates an auxiliary through-lane which is shorter than adjacent through-lanes.

1.2.2 Through-lane use

For any through-lane of a traffic signal approach, the through-lane use is defined as the percentage of all through-traffic on that approach using that lane. For example, for two, three and four through-lane approaches, the target rates of use for the individual lanes would be 50%, 33% and 25%, respectively. It is suggested that the definition of through-lane use could be '*for any through-lane of a traffic signal approach, the through-lane use is the ratio of the through-traffic volume in that lane to the target through-traffic volume for that lane*'. This definition has the advantage that all through-lanes reaching the target would score 1, regardless of the number of lanes. If this topic is researched further, consideration should be given to altering the definition of through-lane use accordingly.

1.2.3 Under-designing

In this study, an intersection described as 'under-designed' has a design life less than the minimum of 10 years which is desirable.

1.3 Background to research

A previous brief study undertaken by *CITY* DESIGN (now GHD) (Jurisich 1999) reviewed the effects of short lanes at signalised intersections. This study indicated that significant capacity gains would be likely at signalised intersections if upstream and downstream short lanes were designed with an appropriate length. Many signalised intersections in Auckland which are thought to be congested have intersection approach lanes which are not long enough. If these lanes were modified or extended, then large benefits could be achieved in making traffic flow efficient, saving travel time and reducing the cost of operating vehicles.

Congestion is a major issue in Auckland and improving delays at major signalised intersections would help to address this. Designing optimum length lanes at congested intersections is likely to be a cost-effective solution for improving traffic flow efficiency, and reducing Auckland's congestion costs. Previous work undertaken by *CITY* DESIGN indicated that increased traffic congestion can worsen accident statistics. Therefore, reducing congestion would probably have benefits for road safety.

Short traffic lanes upstream (caused by lane blockage or short lane length) and short downstream lanes (caused by short merge length) at signalised intersections can considerably affect intersection capacity. Short traffic lanes can lead to signalised intersections being under-designed and reaching capacity well before their general minimum ten-year design life. This can cause the benefit/cost ratios (B/Cs) for upgrading such intersections to be incorrect – Land Transport New Zealand (LTNZ) could be funding inadequate schemes. These short lanes have no guidelines on their required length, which has led to some substandard designs in the past.

The previous *CITY* DESIGN study reviewed the signalised intersection of Mt Eden and Balmoral Roads. This intersection was upgraded a few years ago and should have had a design life of around ten years, but it became congested after two to three years. The short approach and departure lanes at the intersection contributed significantly to its congestion. *CITY* DESIGN investigated lane use on the approaches to the intersection, and usage of the left-hand, middle and right-hand through-lanes was distributed very unevenly (roughly 50%, 40% and 10%, respectively). It is unlikely that the traffic modelling for the original design of this intersection took adequate account of how poorly the short lanes are used. Popular analytical traffic models appear to provide results that suggest short lanes are used more than they really are, unless great care is exercised during calibration. As a consequence, upgrades of an intersection with short lanes can be under-designed.

The signalised Sandringham Road/Balmoral Road intersection has recently been upgraded, with much longer 'short' lanes than the Mt Eden Road/Balmoral Road intersection. At Sandringham/Balmoral, the approach queue storage lanes were designed to accommodate 95th percentile peak hour commuter queues and the adjacent lanes were generally long enough to prevent lane blockage. Downstream merge lanes (including taper) were designed to be 1½ times longer than the 95th percentile upstream queues. Such downstream lane and merge length was considered sufficient to merge traffic comfortably without causing congestion downstream. This downstream merge length was not considered to be excessive, provided that the upstream queue length did not exceed the length of queue that could go through the intersection during a single green signal phase.

With the 'longer' short lanes at the Sandringham/Balmoral intersection, it was expected that lane use at this intersection would be far more evenly distributed than at the Mt Eden/Balmoral intersection.

Both of these intersections have a similar layout, except for the differences between short lane lengths. Because the intersections are in proximity, their traffic flow characteristics are similar (except, maybe, for the trips generated by the St Luke's Shopping Centre west of Sandringham Road). Consequently, comparing lane use at the two intersections would provide very useful data regarding the length of short lanes and the corresponding effect on lane use with little interference likely to arise from other factors that affect short lane use. Basically, the Mt Eden/Balmoral intersection could act as a 'control' for the study of lane use at the Sandringham/Balmoral intersection.

1.4 Investigative approach

The following investigative approach was adopted:

- undertaking a literature review to determine the existence of any guidelines on the required lengths of short lanes and/or the effects of short lanes on lane use;
- collecting traffic volume and queue length information at the signalised Sandringham/ Balmoral and Mt Eden/Balmoral intersections, and comparing lane use;
- collecting traffic survey data at the signalised intersection of Carbine Road and the Southeastern Arterial (SEART), and investigating lane use;
- modelling at the Sandringham/Balmoral intersection, to determine the benefits associated with improved lane use;
- evaluating the economic benefits of lengthening the short lanes;
- investigating ways to improve lane use at the Mt Eden/Balmoral intersection, and reviewing this economically; and
- preparing a list of intersections that could benefit from having lane use reviewed.

2. Literature review

2.1 Overview

We reviewed literature from the Internet and local sources regarding short lane use at intersections, including documents from AUSTROADS, Australian Road Research (ARR), and other Internet sources. This review aimed to examine any existing research information on the topic. A limited quantity of useful information was retrieved.

Generally, approach lane lengths should be able to accommodate 95th percentile peak hour queue lengths. Using traffic simulation models, the necessary lane lengths can be determined by inputting a number of infinitely long lanes and determining the length of the 95th percentile queues.

Published research (AUSTROADS 1988) indicates that the length of through-lanes depends on the amount of storage required for through-vehicles waiting to enter the intersection. AUSTROADS recommends that through-lanes should only be dropped well clear of an intersection, preferably a minimum of 100 m beyond an intersection. The merge taper at the end of a lane should also provide for a rate of lateral movement of preferably no more than 0.6 metres per second (m/s).

2.2 Short through-lane use

Many signalised intersections in New Zealand have underused short through-lanes on approach or departure. Poor lane use is an important issue in operating an intersection, as it can significantly reduce the capacity of an intersection and can also reduce the carrying capacity of the road network.

From the authors' experience and from the literature, we consider the following factors to contribute to poor use of through-lanes:

- **How short approach lanes are:** Approach lanes that are relatively short are likely to overflow or become obstructed, resulting in poor use.
- **The length of an adjacent left-turn lane (signalised):** If a signalised left-turn lane is short and if queues of vehicles turning left can obstruct the adjacent through-lane, then the through-lane may be used less. Motorists who turn left travel more slowly than through-traffic and a long queue of vehicles turning left could delay through-traffic in an adjacent lane.
- **The quantity of traffic turning left:** High volumes of traffic turning left would discourage through-traffic from using a shared lane (through and left-turn), or may reduce the efficiency of an adjacent lane that occasionally becomes obstructed by traffic turning left.
- **Parallel pedestrian phasing and pedestrian volumes:** A parallel pedestrian phase and high pedestrian volumes would reduce how efficiently a vehicle can turn left, which would be likely to adversely affect adjacent through-lanes.

- **The length of an adjacent left-turn slip lane (unsignalised):** Motorists can be reluctant to create a long queue in a short through-lane if the queue is likely to obstruct an adjacent free left turn.
- **The origin and destination of motorists:** Motorists are more likely to use and queue in approach through-lanes that correspond with their origin or destination.
- **The number of lanes available at the intersection:** A short through-lane is less likely to be used with increasing numbers of adjacent through-lanes.
- **The lateral displacement or lane changing required to reach the short through-lane:** The greater the lateral distance required to be traversed to reach a supplementary through-lane, the less likely it is to be used.
- **The length of the green phase signal cycle:** The longer the green signal phase, the greater the likelihood that the saturation flow of the short through-lane would reduce during the green phase. This is because the traffic queuing in the short lane would completely discharge, and would then be fed queuing traffic from an adjacent longer lane, thus relying on its saturation flow.
- **The length of merge distances downstream of the intersection:** Short merge distances downstream from an intersection discourage motorists from using lanes because of the difficulty associated with merging.
- **Congestion levels on the roading network:** If a roading network is not particularly congested then motorists are less likely to go to the effort of changing lanes to reach lanes with shorter queues. Thus, short lanes are likely to have proportionately higher useage under congested conditions.
- **Percentage of heavy commercial vehicles (HCVs):** In general, higher percentages of HCVs mean that motorists are more likely to use kerbside lanes than off-side lanes. HCVs occupy more space and travel at a slower speed than most other vehicles, discouraging following traffic. Consequently, the higher the percentage of HCVs traversing a particular intersection, the less kerbside lanes will be used (this factor could be accounted for in traffic surveys on rates of use by adjusting traffic count to passenger car units).
- **Percentage of buses and location of bus stops:** Frequent bus services and bus stops located near an intersection are likely to discourage motorists from using kerbside lanes.
- **On-street parking/loading**: If on-street parking or loading is permitted at certain times along a section of road near an intersection, this may discourage some motorists from using a kerbside lane at all times.
- **Degree of saturation:** Short lanes can affect lane use at intersection limit lines. The traffic flow on short lanes can be less (because of blockage), and therefore the Sydney Co-ordinated Adaptive Traffic System (SCATS) degree of saturation can be less than otherwise would be if the lanes were used fully. SCATS therefore may allocate less green signal time to the approach than it needs to, since the degree of saturation would be lower. For SCATS to operate correctly, the short lane must be long enough to always discharge at the maximum rate.

Overall, it is considered that short approach and departure through-lanes at signalised intersections are major contributors to poor through-lane use at intersections. The main reasons that intersections are often designed with short lanes are likely to be:

- **Economic reasons:** Reducing the length of short lanes reduces the amount of road-widening necessary, which reduces costs. Road widening costs may include the relocation of underground utility services and land-take, both of which can be prohibitively expensive and may also delay a project.
- **On-street parking, bus lanes, transit lanes and flush medians:** To accommodate additional on-street parking close to an intersection, or to allow bus lanes, transit lanes and/or flush medians to be provided near an intersection, short lanes may be provided.
- **Traffic modelling:** Many analytical traffic simulation models do not effectively model the effects of lane blockage, and thus over-estimate the benefits of short lanes and cause longer lanes to appear uneconomic. This is likely to occur unless the traffic simulations are calibrated carefully, including calibrating short lane use.

2.3 Lane blockage

Lane blockage on approaches to intersections can be caused by vehicle queues in a traffic lane obstructing an adjacent lane. If an approach lane at an intersection is too short to accommodate a vehicle queue fully, then the vehicle queue can block the adjacent lane. Use of the adjacent lane would consequently reduce. Alternative types of lane blockage are illustrated in Figure 2.1.

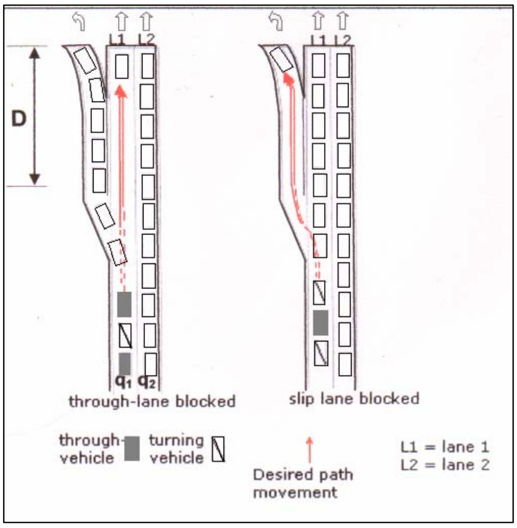

Figure 2.1 Lane blockage of short through-lane and slip lanes at a signalised intersection.

2.4 Short through-lane saturation flows

Açkelik (1989) describes various situations where saturation flows on multi-lane approach roads are reduced because of short lane effects (e.g. when the space for queuing is limited). Açkelik notes that queuing space may be restricted by the limited length of a lane, the limited length of an adjacent lane, on-street parking or a pre-intersection bus lane. Furthermore, Açkelik mentions that the full saturation flow of a short lane is directly related to the length of the short lane, and inversely related to the length of the green phase signal cycle. The full saturation flow of a short lane only occurs while the vehicles originally queuing in the short lane are discharging. Once these vehicles have discharged, the saturation flow would reduce to the saturation flow of the other longer lanes that are available. Equation One illustrates this.

$$S_1 \text{ (vehicles per hour)} = \frac{3{,}600 \times \mathbf{D} \text{ (metres)}}{j \text{ (metres per vehicle)} \times g \text{ (seconds)}}$$

where:
S_1 *= effective saturation flow of a short lane, up to a maximum of normal full lane saturation flow,*
D *= effective length of the short lane,*
j *= the amount of queuing space required per vehicle (around 6.5 m), and*
g *= duration of the green signal phase in seconds.* [Equation One]

The effective use of a short lane can be further reduced by lane blockage, which is affected by the relative vehicle arrival rates in the short (and adjacent) lanes, as shown in Equation Two.

$$D \text{ (metres)} = \frac{q_1 \text{ (vehicles per hour)}}{q_2 \text{ (vehicles per hour)} \times D_t \text{ (metres)}}$$

where:
D *= effective length of the short lane,*
D_t *= full length of the turn slot,*
q_1 *= turning flow arrival rate, and*
q_2 *= adjacent lane arrival flow rate.* [Equation Two]

3. Short through lane use – site surveys

3.1 Overview

The traffic at the signalised Sandringham/Balmoral and Mt Eden/Balmoral intersections was surveyed for the purpose of comparing lane use on the Balmoral Road through-lanes of both intersections. The aerial plans and traffic count information for both intersections can be referred to in Appendices A and B. The three through-lanes at both intersections have adjacent right-turn pockets and 'neutral' downstream destinations. For maximum traffic flow efficiency, it would be desirable for these through-lanes to be used evenly, i.e. having 33% of the total through-traffic using each lane. However, this is only likely to occur if all the lanes are of an equivalent full (indefinite) length.

At the Mt Eden/Balmoral and Sandringham/Balmoral intersections, the left-hand (kerbside) through-lanes on Balmoral Road are shorter than the adjacent through-lanes, and consequently one would expect them to be used less. The short lanes and left-turn slip lanes at the Sandringham/Balmoral intersection are longer than those at the Mt Eden/Balmoral intersection, so it was expected that through-lane use at the Sandringham/Balmoral intersection would be more evenly distributed.

3.2 Results from the Mt Eden/Balmoral intersection

The survey results showing short through-lane use for the average of the morning and evening commuter peaks and the off-peak period for the Mt Eden/Balmoral intersection are shown in Table 3.1.

Table 3.1 illustrates the following key points regarding the Mt Eden/Balmoral intersection:

- For all three periods studied, the short through-lanes (on the left) on Balmoral Road are used at a lower rate (11.5%) than the adjacent through-lanes (in the middle and on the right (40.5% and 48% respectively)).
- The rate of use for the short through-lanes is lower at times when the intersection is less busy, being around 8.5% during the off-peak compared to an average of 12.5% during the a.m. and p.m. peaks. This demonstrates that motorists are reluctant to use short lanes when traffic flow conditions are not congested. It also demonstrates that in congested traffic conditions, short lane use is likely to be higher.

Table 3.1 Short through-lane use comparison at the Mt Eden / Balmoral intersection during a.m. and p.m. peaks, and off-peak periods.

Mt Eden / Balmoral intersection features	Balmoral westbound			Balmoral eastbound		
	left-hand	middle	right-hand	left-hand	middle	right-hand
Approach lane length	95 m	full	full	100 m	full	full
Departure lane length	120 m	full	full	125 m	full	full
Approach and departure lane lengths[a]	215 m	full	full	225 m	full	full
Morning peak traffic volumes[b]	80	284	380	124	418	491
Morning peak rate of use[c]	11%	38%	51%	12%	40%	48%
Off-peak traffic volumes	49	273	316	57	265	306
Off-peak rate of use	8%	43%	49%	9%	42%	49%
Evening peak traffic volume	154	497	532	138	355	464
Evening rate of use	13%	42%	45%	14%	37%	49%
Total traffic volumes	283	1054	1228	319	1038	1261
Total rate of use	11%	41%	48%	12%	40%	48%

Notes to Table 3.1:

a The length of a short lane is the sum of the approach lane, the downstream lane and the distance required to traverse the intersection.

b Volumes include HCVs, which have been equated to 2 passenger car units each.

c The rate of use applies to through-vehicles only and does not include any vehicles turning left which were associated with the left-hand lane. This is done in order to emphasise how through-vehicles use the lanes. Also, it is difficult to determine how left-turning motorists affect through-lane use for different slip lane lengths, though it is noted that the shorter and busier left-turn slip lane, the greater the impact of vehicles turning left. The Balmoral Road eastbound lane at the Mt Eden/ Balmoral intersection is a shared through- and left-turn lane (with no slip lane), and motorists who turn left are likely to have a substantial effect on how this through-lane in particular is used. The data presented in Tables 3.1 and 3.2 for this lane exclude the 115, 102 and 93 vehicles per hour turning left from this lane during the morning peak, off-peak and evening peak respectively. The rates of use for this lane are omitted from Figures 3.1 and 3.2 owing to its different effect on through-lane use.

It should be noted that the Balmoral eastbound kerbside lane is a shared through- and left-turn lane, and consequently motorists turning left would decrease the percentage of through-vehicles using this lane. Conversely, the Balmoral westbound kerbside lane has a 15 m slip lane. Since the majority of motorists would be able to turn left unimpeded, they would have limited impact on how the kerbside lane is used. Consequently, the percentage of through-vehicles using the Balmoral eastbound lane should be treated with caution, though its rate of use is similar and slightly higher (12%) than the average rate of use for the Balmoral westbound kerbside lane (11%).

It is also noted that different lane configurations at other signalised intersections would be likely to create somewhat different results. Also, as discussed in Chapter 2.2, various factors can contribute to poor through-lane use at an intersection.

3.3 Results from the Sandringham/Balmoral intersection

The short through-lane use results for the Sandringham/Balmoral intersection are summarised in Table 3.2.

Table 3.2 includes the feature 'Adjusted to congested flow', which is explained as follows: The Mt Eden intersection is generally saturated during peak commuter hours, which would be likely to cause any short lanes to have a higher rate of use than if the intersection was not saturated. During off-peak periods at the Mt Eden/Balmoral intersection (2005 traffic count), the Balmoral short lanes carry around 8.5% of the through-traffic, while during peak periods, the Balmoral short lanes carry around 12.5% of the through traffic (about 47% higher use). Conversely, the Sandringham/Balmoral intersection is operating well below capacity during commuter peaks, and the rate of use for the short lanes is likely to be lower than if operating at capacity. This is illustrated by the fact that during off-peak periods, the Sandringham/Balmoral intersection short lanes carry around 15% of the through-traffic, while during peak periods, the Balmoral short lanes carry around 17% of the through-traffic (only about 13% greater use). To simulate the Sandringham/Balmoral intersection operating at capacity (thus enabling a more effective comparison to be made with the Mt Eden/Balmoral intersection), the rate of use for the short lanes could be increased by around 47%. However, the kerbside through-lanes at the Mt Eden/ Balmoral intersection are poorly used because they are particularly short. Consequently, increasing the rate of use for the Balmoral short lanes at the Sandringham/Balmoral intersection by a conservative figure of around 20% would be considered reasonable. The 'Adjust[ment] to congested flow' in Table 3.2 is calculated by increasing the rate of use by 20%.

Table 3.2 Short through-lane use at the Sandringham / Balmoral intersection during the morning and evening peaks and the off-peak period.

Sandringham / Balmoral intersection features	Balmoral westbound			Balmoral eastbound		
	left-hand	middle	right-hand	left-hand	middle	right-hand
Approach lane length	210 m	full	full	200 m	full	full
Departure lane length	180 m	full	full	115 m	full	full
Approach and departure lane lengths	390 m	full	full	315 m	full	full
Morning traffic volumes	129	284	320	93	242	288
Rate of use	18%	39%	43%	15%	39%	46%
Adjusted to congested flow	22%	37%	41%	18%	38%	44%
Off-peak traffic volumes	108	230	320	95	257	333
Rate of use	16%	35%	49%	14%	38%	48%
Adjusted to congested flow	19%	33%	48%	17%	37%	46%
Evening traffic volumes	181	332	408	163	391	438
Rate of use	20%	36%	44%	16%	39%	45%
Adjusted to congested flow	24%	34%	42%	19%	37%	44%
Total traffic volumes	418	846	1048	351	890	1059
Total rate of use	18%	37%	46%	15%	39%	46%
Adjusted to congested flow	22%	35%	43%	18%	38%	44%

3.4 Comparing the intersections

The key points noted regarding Table 3.1 are reinforced by Table 3.2. However, short lane use is considerably higher in Table 3.2. This indicates that the longer slip lanes and 'short' through-lanes at Sandringham Road have enhanced lane use, though the distribution is not evenly balanced. Table 3.3 compares the average rate of use and short through-lane-lengths at both intersections.

Table 3.3 Average short through-lane use and lane lengths compared for both intersections during three commuter periods.

Features	Balmoral westbound				Balmoral eastbound			
	slip lane	left-hand	middle	right-hand	slip lane	left-hand	middle	right-hand
Sandringham/Balmoral approach lane	70 m	220 m	full	full	35 m	210 m	full	full
Sandringham/Balmoral departure lane	–	170 m	full	full	–	105 m	full	full
Sandringham/Balmoral lane lengths	70 m	390 m	full	full	35 m	315 m	full	full
Mt Eden/Balmoral approach lane	15 m	105 m	full	full	0 m	110 m	full	full
Mt Eden/Balmoral departure lane	–	110 m	full	full	–	115 m	full	full
Mt Eden/Balmoral lane lengths	15 m	215 m	full	full	0 m	225 m	full	full
Percentage change – lane length	466%	181%	–	–	∞	140%	–	–
Average rate of use at Sandringham/Balmoral	–	18%	36%	46%	–	15%	39%	46%
Average rate of use at Sandringham/Balmoral (adjusted)	–	22%	34%	44%	–	18%	38%	44%
Average rate of use at Mt Eden/ Balmoral	–	11%	41%	48%	–	12%	40%	48%
% change in rate of use between intersections	–	164%	88%	96%	–	125%	98%	96%1
% change in rate adjusted	–	200%	83%	92%	–	150%	95%	92%

Note to Table 3.3: The right-turn pockets at both intersections are linked to flush medians, and are thus considered to be infinitely long.

From Table 3.3, it is evident that the Balmoral Road lanes at the Sandringham/Balmoral intersection are used more evenly than at the Mt Eden/Balmoral intersection. The lanes at the Sandringham/Balmoral intersection are used at a higher rate and at a lower rate for the full length lanes. However, lane use for the Sandringham/Balmoral intersection is still far from uniformly distributed.

Assuming no other factors are involved, we can conclude that the higher rate of use for the lanes at the Sandringham/Balmoral intersection is because the left-turn slip lanes are longer and so are the approach and departure lanes. Indeed, the increased rate of use for the short lanes correlates to (and is slightly less than) the percentage increase in the length of the approach and departure lanes.

Also, it should be noted that if the Sandringham/Balmoral intersection had been operating at close to capacity, then the rate of use of its short lanes would probably have been substantially higher (conservatively, around 20% higher).

The increased use of the lanes would improve the operational efficiency of the intersection. However, benefit/cost analysis would be required to determine if the improvement in operational efficiency is warranted in comparison to the construction cost of providing longer lanes.

4. Short through-lane length versus lane use

Currently, no technical design data that accurately predicts the expected usage of a short lane based on its length are available. Technical designers generally rely on traffic models to reach such assessments. However, most analytical traffic models assign traffic using the equal utilisation technique. This is likely to be optimistic if one allows for the various factors that can affect lane use that traffic models do not take into consideration (see Chapter 2.2).

Useful technical data could be acquired by measuring the lengths of short upstream and downstream lanes, and surveying the short through-lane use. The lane lengths and associated lane usage could be compared (and any other relevant factors noted or neutralised, such as slip lane length, origin and destination of motorists, the number of through- lanes, the relative lengths of the approach and departures, and the level of traffic congestion).

With these data, a 'best-fit' graph could be created. Examples of these graphs are shown in Figures 4.1 and 4.2 for a left-side merge with three through-lanes, the slip lane length ignored and using a total of three data samples from both the Sandringham/Balmoral and Mt Eden intersections.

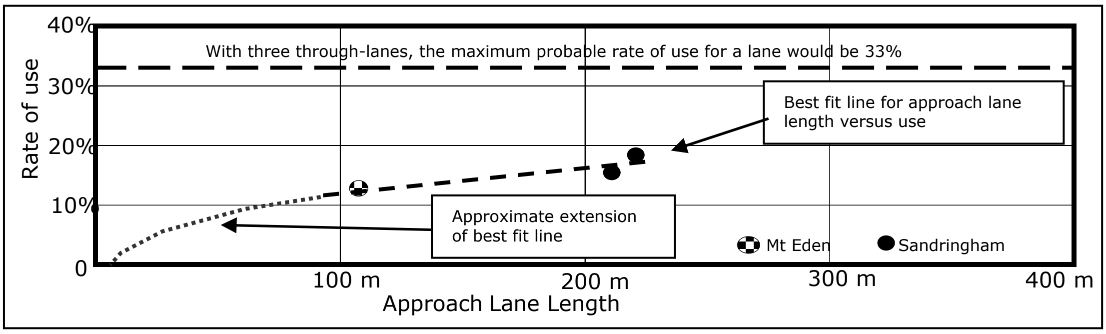

Figure 4.1 Approach length versus use in short through-lanes at both intersections.

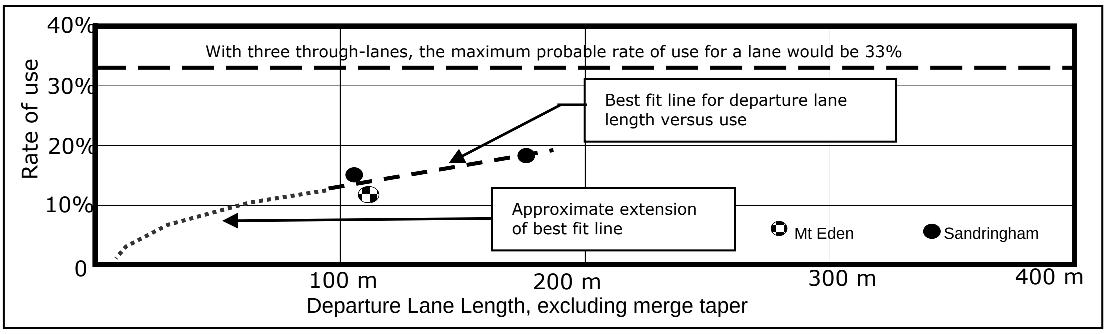

Figure 4.2 Departure length versus use in short through-lanes at both intersections.

For a simplified analysis, Figures 4.1 and 4.2 can be combined to create Figure 4.3, which amalgamates the length of the approach and departure short lanes. When interpolating information from Figure 4.3, we shall assume that the short approach and departure lanes both have adequate, similar lane lengths. Figure 4 includes the short lane rate of use predicted by the uncalibrated analytical traffic models used for the Sandringham/Balmoral and Mt Eden/Balmoral intersections.

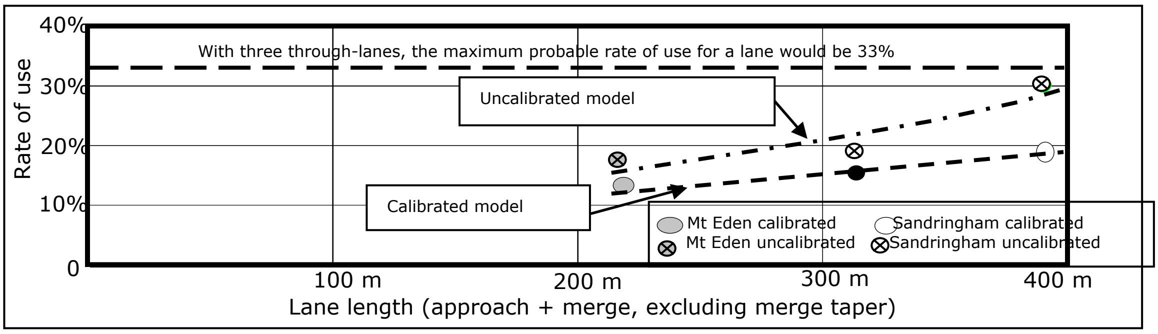

Figure 4.3 Short through-lanes – total length versus rate of use for calibrated and uncalibrated models.

Figure 4.3 identifies a similar relationship between lane use and approach or departure lane length.

Figure 4.3 also shows that the actual measurements of short lane use at the two intersections surveyed are substantially less (around 40% lower) than what is estimated by the uncalibrated traffic model, especially for longer 'short' lane lengths. If traffic models are calibrated, then this need not be an issue. However, it can be difficult or impossible to calibrate proposed designs, particularly if they are substantially different. In the case of a new proposed short through-lane, any attempt at calibration is likely to be inaccurate and a traffic model would probably over-estimate the benefits of the short lane substantially.

In this research project, SIDRA was used as a traffic modelling tool. However, SIDRA is unlikely to be the only traffic model that provides imprecise information regarding short lane use when the default values of equal lane use are employed. Highly accurate analytical and simulation models for movement in short and adjacent traffic lanes are not generally available, although proprietary models do include algorithms that make order-of-magnitude allowance for the influence of short lanes. Since very limited information is available regarding short through-lane use, constructing accurate models is difficult. SIDRA allows users to get around this problem by allowing users to insert through-lane usage rates if they are known. This research project has provided some values that can be used.

At the Sandringham/Balmoral intersection, the eastbound short through-lane is used somewhat less than the westbound short through-lane. This could be attributed to (i) the relatively short length of the eastbound merge and (ii) the relatively short length of the eastbound left-turn slip lane (though at the Mt Eden/Balmoral intersection, the Balmoral

Road short lanes are used in a similar way, even though the eastbound approach has no slip lane).

It should be noted that the data source is limited, that the results are not significant and that further research is required. Also, many other factors could have affected the results, as discussed in Chapter 2.2.

If the database was extensive enough to achieve statistical significance, then it would enable engineers to predict the expected rate of use for proposed short lanes at intersections accurately. This information could then be used during the traffic modelling process, which would enable improved design and greater accuracy in modelling and economic analysis.

5. Lengthening short through lanes – B/C analysis

An analytical traffic model was set up to replicate the existing layout and operation of the Sandringham/Balmoral intersection. Queue lengths and lane use were calibrated for the model using on-site measurements of lane-by-lane queues and traffic volumes. Saturation flows and lane use were adjusted during the calibration process. In order to be conservative, the estimated 20% increase in use for congested conditions at the Sandringham/Balmoral intersection was not used in the traffic modelling.

It was noted prior to calibration that the traffic model consistently over-estimated how the Balmoral Road short through-lanes are used, and significant lane use calibration was required in order to simulate the existing situation accurately.

Using the first traffic model, a second model was set up, but for this model the Balmoral Road short lanes (approach and departure) were shortened to a length similar to the short lanes at Mt Eden Road, while the slip lane arrangements were essentially unchanged (to minimise any effect that the factors unrelated to short through-lane length might have on the model).

Lane lengths similar to those at Mt Eden Road were chosen because accurate on-site surveys had been made of how the short lanes at the Mt Eden/Balmoral intersection were used, and this information would enable accurate calibration of the second model. The usage figure for the kerbside eastbound Balmoral lane at the Mt Eden/Balmoral intersection includes vehicles turning left as well as those travelling straight through. However, since this usage figure was similar to that of the opposite kerbside approach, choosing this rate of use in the economic analysis was considered acceptable. At the Sandringham/ Balmoral intersection the slip lanes for left turns are considered to be long enough to reduce the effect of left-turns substantially (35 m and 70 m). An economic comparison of the two calibrated models would reveal the financial benefits attributed to (theoretically) lengthening the short Balmoral Road through-lanes.

The operational efficiency of these two traffic models were compared for the a.m peak, off-peak and p.m. peak periods over a 25–year analysis period. The financial benefits attributable to the lengthened short lanes were evaluated in terms of reducing the cost of operating a vehicle and saving travel time. The financial benefits attributable to congestion costs and CO_2 emission costs were not included in the analysis. If accounted for, the benefits attributable to the works would have been enhanced. The financial cost of lengthening the short lanes was evaluated, taking into account probable utility service relocation costs and land-take costs.

The geometric layouts, traffic model outputs, and B/C calculations for the analysis can be found in Appendix C. The B/C calculations have been undertaken according to standard procedures which are outlined in the LTNZ (formerly Transfund New Zealand) Project

Evaluation Manual (LTNZ 2005). The economic results from lengthening short lanes at the Sandringham/Balmoral intersection are summarised in Table 5.1.

Table 5.1 An economic analysis of lengthening short through-lanes at the Sandringham / Balmoral intersection.

Option	Cost[a]	Benefit[b]	FYRR[c]	B/C
Lengthen the Balmoral short through-lanes westbound and eastbound at Sandringham Road.	$627,000	$3,063,000	7%	4.9

Notes to Table 5.1:

a. Cost: Rough order cost estimate (+/-20%), discounted by one year with nominal amounts assigned to utility service relocations on a per metre basis, and no land-take costs.

b. Benefit: 25-year benefits composed of travel time savings and vehicle operating cost savings.

c. FYRR: First Year Rate of Return.

In summary, lengthening the combined approach and departure lengths of the westbound and eastbound Balmoral short lanes by 175 m and 100 m (respectively) creates a 25–year benefit of around $3 million. At a construction cost of $690,000, this generates a B/C of 4.9, indicating that the project is beneficial economically.

Also, it is noted that the benefits calculated above are conservative and do not include congestion costs and CO_2 emission costs.

6. Alternative short through-lane configurations

6.1 Right-hand short through lanes: SEART / Carbine intersection surveys

Traffic surveys were undertaken at the signalised intersection of the Southeastern Arterial (SEART) and Carbine Road for the purpose of reviewing how the three westbound through-lanes on SEART are used. The way these lanes were used was of particular interest because the short approach and departure lanes are very long (around 600 m) and located on the right (i.e. the two full-length lanes are on the left (kerbside)).

A right-hand merge design was originally implemented at this intersection since most motorists would want to keep to the right-hand lane to turn right downstream at the Southern motorway. If a short through-lane had been installed on the left-hand side, then it would not be used frequently.

The location, layout and traffic survey data for the intersection can be referred to in Appendix D. The survey results are summarised in Table 6.1.

Table 6.1 SEART westbound lane use at the SEART / Carbine intersection during peak periods.

Details	SEART westbound through-lanes		
	left-hand	middle	right-hand
Approach and departure lane lengths	full	full	–
Morning traffic volume	649	622	603
Percentage of total	35%	33%	32%
Evening traffic volume	459	425	305
Percentage of total	38%	36%	26%
Average traffic volume	554	524	454
Percentage of total	36%	34%	30%

The tabulated results indicate that the three SEART through-lanes are used relatively evenly, with slightly less traffic using the short lane on the right. The relatively even rates of use are attributed to:

- the extended length of the 'short' through-lane,
- the short lane being located on the right,
- the short lane on the right being unaffected by friction caused by slow-moving traffic turning right, and
- the predominant downstream destination being the motorway, which is right-side.

Since motorists are likely to prefer to use the right-hand traffic lanes in congested traffic and since the downstream destination is also on the right, motorists are inclined to use the short lane, thus enhancing its rate of use.

Furthermore, when congestion is lower (during the p.m. peak), the short lane is used less, which corresponds to the off-peak usage survey results at the Sandringham/ Balmoral and Mt Eden/Balmoral intersections.

From this, we can conclude that rate of use for short approach and departure through-lanes may be enhanced by lengthening the short through-lanes and by locating the short lanes on the right, provided the downstream destination of motorists is suitable.

In order to encourage better lane use, the short through-lanes could be placed to the left or to the right, depending on:

- the proportion of turning traffic wishing to share the short lane at the subject intersection, and
- the demands of traffic turning left/right at the next major intersection downstream.

6.2 Crash analysis – right-hand versus left-hand short lanes

We envisaged that short through-lanes on the right could have an adverse impact on crash statistics. In particular, additional sideswipe, lane-changing and rear-end accidents could be expected. This is because right-hand traffic travels faster and this could create difficulty with respect to the downstream merge. Motorists generally do not expect a right-hand merge, as merges are typically located on the left. Furthermore, the New Zealand 'right-hand rule for giving way' is likely to be clearer to motorists merging in kerbside lanes, rather than right-hand lanes.

Because of these expectations, we reviewed the accidents that had occurred (and been recorded) in the eastbound and westbound lanes of SEART on both sides of Carbine Road. A crash analysis system (CAS) plot for SEART will be found in Appendix E. We analysed non-injury and injury crashes for the past five years (2000–2004) to identify if an historic safety problem related to merge crashes exists; the Traffic Crash Reports were referenced to clarify the data.

Over the past five years, seven reported non-injury accidents that possibly relate to lane-changing or merging issues have occurred, five westbound and two eastbound (LTNZ 2004). Such accident statistics indicate a pattern of moderate problems with changing lanes.

As a comparison, we analysed crash statistics for a left-hand merge on Balmoral Road in both westbound and eastbound directions at both the Sandringham/Balmoral and Mt Eden/Balmoral intersections. The results showed a total of two reported non-injury accidents that may be related to merges near the intersections over the past five years (LTNZ 2004).

Overall, the right-hand merge crash statistics on SEART appear to be worse than the left-hand merge crash statistics on Balmoral. However, SEART is more congested and operates at a higher speed than Balmoral Road, characteristics which are both likely to be factors which aggravate crashes. Also, the crash data is limited and restricted to non-injury accidents only. Crash analysis which is more extensive would be required in order to extrapolate this result significantly to the wider roading network.

6.3 Alternative short through-lane configurations

The traffic surveys undertaken at the SEART/Carbine intersection have provided a preliminary indication that short right-hand through-lanes are likely to have significantly higher rates of use than short through-lanes on the left.

Part of the reason that motorists are reluctant to use short approach lanes is because they are usually associated with short downstream merges.

The two alternative short through-lane arrangements studied in this report are shown in Figure 6.1:

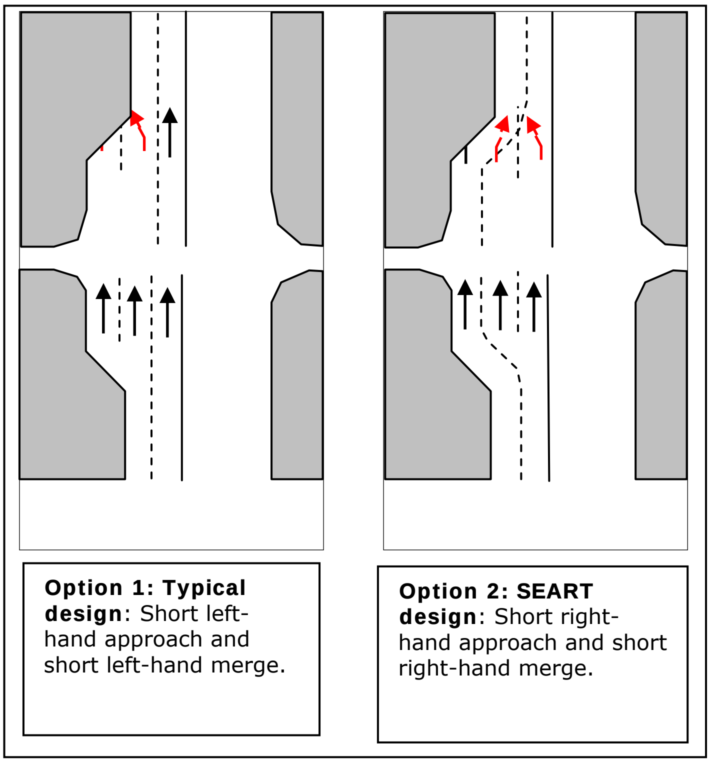

Figure 6.1 Short lane configurations: typical design and the SEART design.

In Figure 6.1, Option 1 illustrates a typical short lane arrangement, with both the short approach lane and the short departure lane on the left. Option 2 shows the SEART lane arrangement, with both the short approach lane and short departure lane on the right. SEART has relatively evenly balanced lane use, and we considered that the short lane arrangement has contributed to this result (in combination with the right-hand downstream destination and the fact that the SEART short lanes are longer than what is typical of short lanes). Two alternative short through-lane configurations are suggested in Figure 6.2.

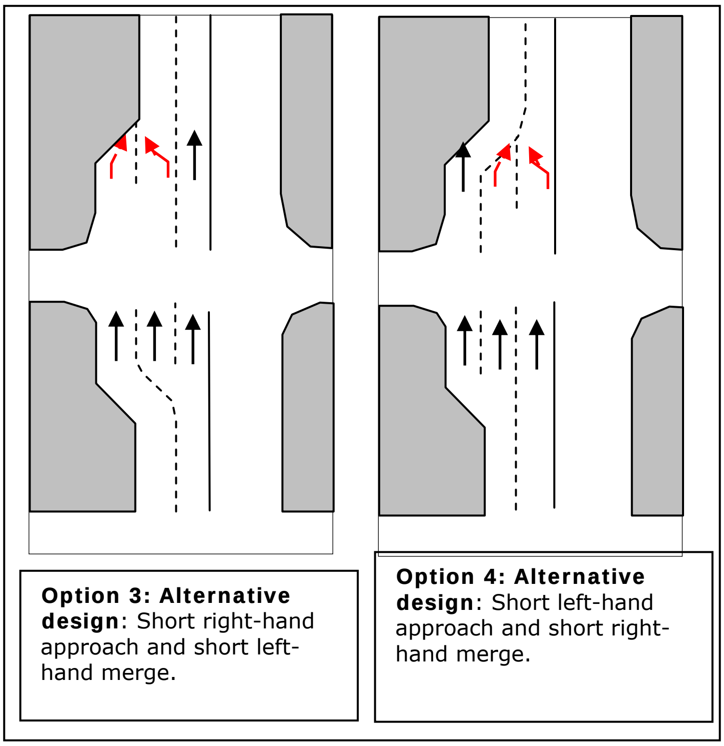

Figure 6.2 Alternative short lane configurations for approaches and merges.

In Figure 6.2, Options 3 and 4 illustrate possible alternative short through-lane configurations (not suitable at SEART because of the destination issue). Option 3 is designed so that the short approach is on the right and the short departure lane is on the left, while Option 4 has the reverse. These arrangements could encourage more evenly balanced lane use than Option 1. However, such design layouts could worsen crash statistics because of increased vehicle attrition and potential confusion for motorists. Such lane arrangements may be infeasible if traffic volumes at the two merging lanes exceed the capacity of a single lane (during the green signal phase). Intersections designed in such a manner have not been identified in New Zealand.

Consideration should be given to conducting a trial of Option 2 to study the results further. Suitable intersections should be identified for the establishment of right-hand short through-lanes. Traffic surveys and analysis should be undertaken before and after the works to establish the net impact on lane use, traffic flow efficiency and road safety. If right-hand short lanes have significantly improved short lane use, then considerable economic benefits could be derived.

Options 3 and 4 are not considered worthy to investigate further at this stage because of their likely adverse impact on road safety and the lack of available sites to survey.

7. Proposed upgrade of the Mt Eden/Balmoral intersection

7.1 Lengthening short through-lanes at the Mt Eden/ Balmoral intersection

If the left-turn slip lanes and short through-lanes on Balmoral Road at the Mt Eden/Balmoral intersection were lengthened in a manner similar to the Balmoral Road lane lengths at the Sandringham/Balmoral intersection, then the economic results would be similar to that calculated in Chapter 5 (see Table 7.1).

Table 7.1 Lane lengthening - economic analysis applied to the Mt Eden/Balmoral intersection.

Option	Cost*	Benefit**	FYRR	B/C
Install left-turn slip lanes and lengthen the short approach and departure Balmoral Road lanes by a total of 270 m (around 65 m extension on both approaches and both merges).	$627,000	$3,063,000	7%	4.9

Notes:
***Cost:** Rough order cost estimate (+/- 25%) with nominal amounts assigned to utility service relocations on a per metre basis, and assumed land-take costs.
****Benefit:** 25-year benefits composed of savings in travel time and cost of operating vehicles.

Figure 7.1 below illustrates how the short lanes could be lengthened:

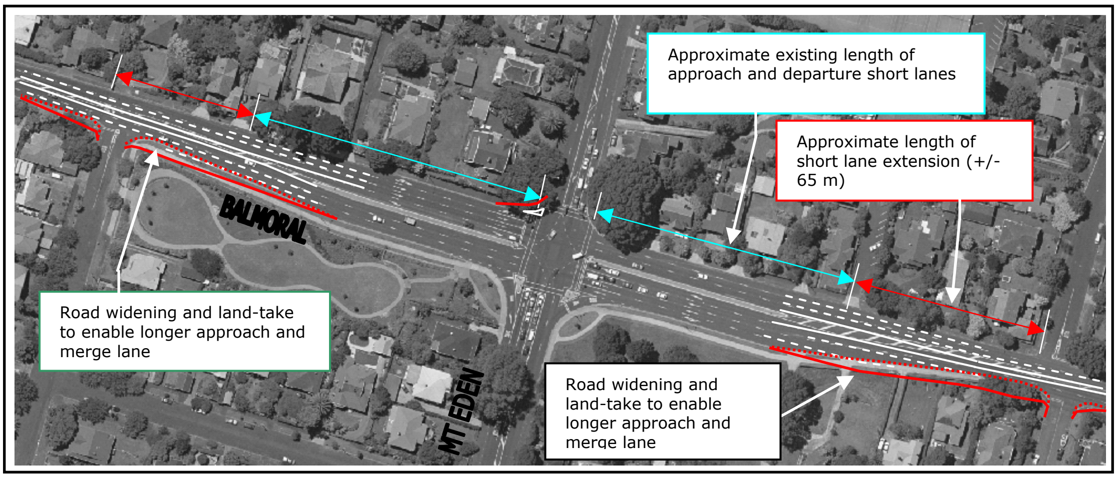

Figure 7.2 Proposal to lengthen short lanes at the Mt Eden/Balmoral intersection.

Obviously, more detailed analysis would be required to confirm this rough assessment, but overall, a proposal to lengthen the Balmoral Road short lanes at the Mt Eden/Balmoral intersection appears to be feasible and economically viable.

For some projects, it may be appropriate to develop the short lanes in stages. It could be cheaper to build short lanes which are not used optimally but could provide an acceptable level of service for a number of years, with the objective of lengthening the short lanes at a later date. Incremental economic analysis could be used to establish how to stagger the proposed works.

7.2 An alternative short through-lane configuration at the Mt Eden / Balmoral intersection

The following plan shows an alternative lane arrangement for improving lane use and operational efficiency along Balmoral Road at its intersection with Mt Eden Road. Only road-marking changes are required, with no road widening. Further investigation would be required before implementing this proposal, including a review of downstream destinations. Figure 7.2 illustrates a right-hand short lane on the approach and on the downstream merge:

Figure 7.2 Possible road-marking / layout changes for the approach lanes and downstream merges at the Mt Eden / Balmoral intersection.

Approach through-lane use would be likely to be more evenly balanced with the lane arrangement in Figure 7.2. However, several concerns exist regarding this lane arrangement:

- The long downstream kerbside lanes may not be fully used, since the kerbside approaches would need to accommodate vehicles turning left;
- A predominant destination on the right is not evident at this intersection, so this lane arrangement may not achieve lane use as evenly balanced as that achieved at SEART;
- Potential exists for crash statistics to be adversely affected, which would need to be studied further. Enhanced merge warning signage could help to prevent a problem with crashing on merges.

8. Short through lanes in New Zealand

Major cities throughout New Zealand have signalised intersections with short through-lanes. These short lanes are unlikely to be used frequently, adversely affecting the intersections' capacity.

To provide an example of the potential for improving lane use and reducing congestion at existing signalised intersections throughout New Zealand, we selected some congested intersections with short lanes for preliminary review. Intersections were selected because they:

- were major intersections with a high level of vehicle congestion;
- had short lanes;
- generally allowed the lengthening of the short lanes to be feasible without implementation/construction being exorbitantly expensive (i.e. no building demolition and a limited amount of land-take).

Aerial plans for ten selected intersections are shown in Appendix F. The list of intersections is given below in Table 8.1.

No.	Intersection
1	Balmoral Road/Dominion Road
2	Dominion Road/Mt Albert Road
3	Great North Road/Carrington Road
4	Manukau Road/Greenlane West
5	New North Road/Blockhouse Bay Road
6	New North Road/Richardson Road
7	New North Road/Sandringham Road
8	New North Road/St Lukes Road
9	Tamaki Drive/Patterson Avenue
10	Great South Road/Greenlane

Table 8.1 Intersections in Auckland with short lanes suitable for upgrading.

This list of intersections is not comprehensive and is not listed in order of priority. Many more major intersections in cities throughout all New Zealand could benefit from such works.

For the selected intersections, the plans in Appendix F illustrate how short lanes could be lengthened to improve lane use. Based on the economic results obtained from the analysis undertaken at the Sandringham/Balmoral intersection, it is likely that the works illustrated on the plans would be economically viable.

9. Conclusions

9.1 Short through-lane use – survey results

The traffic surveys taken at the Sandringham/Balmoral and Mt Eden/Balmoral signalised intersections were used to compare lane use on the Balmoral Road short through-lanes of both intersections. They yielded several key results:

- At the Mt Eden/Balmoral intersection during all three commuter periods studied, the short through-lanes (located on the left) on Balmoral Road were used less on average (11.5%) than the adjacent through-lanes located in the middle and on the right (40.5% and 48% respectively). Also, the rate of use for the short through-lanes was lower when the intersection was less busy, being an average of 8.5% during the off-peak compared to an average of 12.5% during the a.m. and p.m. peaks.
- At the Sandringham/Balmoral intersection, the average rate of use for the longer 'short' lanes (16.5%) was higher than that of the reduced length 'short' lanes at the Mt Eden/Balmoral intersection (11.5%). Also, if the Sandringham Road rate of use was adjusted by the effects of greater congestion, it would probably have been around 20%.

In general, short slip lanes and short approach and departure through-lanes cause short through-lanes to be used less.

9.2 Through lane length versus lane use

A preliminary comparison was made between short slip lane and short through-lane lengths and use. They are directly correlated. Short lanes were used much less than was estimated by a traffic model for an equivalent lane length. Furthermore, the graphs indicated that short approach and departure lanes both affected lane use in the same way.

However, the data source was limited and the results are therefore not significant. Useful technical data would be obtained by undertaking a detailed study comparing the lengths of short upstream and downstream through-lanes, and surveying their associated rates of use. If the database was extensive enough to achieve statistical significance, then the results would enable engineers to predict the expected use of proposed short lanes at intersections accurately. This information could be used during traffic model calibration, enabling improved design and greater accuracy in modelling and economic analysis.

9.3 Lengthening short through-lanes – economic analysis

The B/C value of lengthening the slip lanes and short through-lanes at the Sandringham/Balmoral intersection was determined by economic analysis. A 25–year benefit of around $3 million could be created by:

- lengthening the slip lanes
- lengthening the short through-lanes on Balmoral Road so that the westbound approach and departure lanes combine to the total length of 175 m, and the equivalent eastbound approach and departure lanes combine to have a total length of 100 m.

At a construction cost of $627,000, this would generate a B/C value of 4.9, indicating that the project was beneficial economically. The cost of the additional works is relatively small in comparison to the overall cost of the original upgrade (around $7 million).

9.4 Short through-lanes on the right: SEART/Carbine surveys

Traffic was surveyed at the signalised SEART/Carbine intersection for the purpose of reviewing how the three westbound through-lanes on SEART are used. These lanes include a lengthy 'short' approach and departure through-lane on the right. The results indicated that the three through-lanes were used relatively evenly, which was attributed to:

- the length of the 'short' through-lane,
- the short lane being located on the right,
- the short lane on the right being unaffected by friction caused by slow-moving traffic turning right, and
- the predominant downstream destination being the motorway, which is on the right.

We concluded that use of the short approach and departure through-lanes may be enhanced by lengthening the short through-lanes and by placing the short lane on the right, provided the predominant downstream destination for motorists is suitable.

A right-hand merge may worsen non-injury accident statistics. However, if further research determined that this was an issue, accident remedial measures, such as enhanced signage or road marking, could mitigate the problem.

9.5 An alternative short through lane configuration

A short approach lane and short departure lane on the right could be a cheaper alternative short through-lane configuration which may improve short lane use. This lane configuration should be investigated further, with trials at suitable locations.

9.6 Proposed upgrade of the Mt Eden/Balmoral intersection

A proposal to lengthen the Balmoral Road slip lanes and short through-lanes at the Mt Eden/Balmoral intersection appears to be economically viable, but the analysis was approximate and further investigation would be required to confirm the result.

Also, a right-hand merge was suggested as an alternative lane arrangement for improving lane use and operational efficiency along Balmoral Road at its intersection with Mt Eden Road. Only road-marking changes are required and no road widening. Further investigations would be required before implementing such a proposal, including a review of downstream destinations and merge capacity.

9.7 Short lanes in New Zealand

Ten signalised intersections have been identified in Auckland that could benefit from lengthening the short approach and departure lanes. The plans in Appendix F illustrate how the short lanes could be lengthened to improve lane use at the selected intersections. Based on the economic results obtained from the analysis of the Sandringam/Balmoral intersection, the works illustrated on the plans are likely to be economically viable, but this would need to be investigated further. Many more intersections in major cities throughout New Zealand could benefit from similar works.

10. Recommendations

1. This research report should be distributed to all road controlling authorities, as it would increase general awareness regarding the shortcomings of short through-lanes being poorly used at intersections. The guide in Appendix H provides preliminary information that should assist practitioners to predict and improve short through-lane use.

2. A statistically significant database should be created to enable engineers to predict the expected rate of use for proposed short through-lanes at intersections accurately, which could be used during traffic model calibration. This would enable improved analysis and design, and greater accuracy in modelling and economic assessment. A methodology for further research is suggested in Appendix G.

3. An investigation and trial should be conducted to evaluate the costs and benefits of short right-hand approaches and merges at intersections as an alternative short through-lane configuration.

4. Councils should consider investigating lengthening short through-lanes at congested intersections in cities throughout New Zealand. A preliminary investigation of ten intersections has indicated the economic viability of such a project. At the Sandringham/Balmoral intersection, the theoretical short lane lengthening created a 25–year saving of around $3 million. The works proposed for the ten selected intersections would be likely to create similar savings, with an overall saving of around $30 million.

11. References

Açkelik, R. 1989. Traffic signals: capacity and timing analysis (4th revision). *Australian Road Research Board 123.* Australia: ARRB.

AUSTROADS. 1988. *Guide to Traffic Engineering Practice Part 5 – Intersections at Grade*. Sydney: AUSTROADS.

Land Transport New Zealand 2005. *Project Evaluation Manual*. Wellington: Land Transport New Zealand.

Land Transport New Zealand. 2004. CAS (Crash Analysis System). *https://securecas.ltsa.govt.nz*

Jurisich, I. 1999. Mt Eden Rd/Balmoral Rd intersection lane utilisation and lane blockage study. Appendix G in *Sandringham Rd/Balmoral Rd/St Luke's Rd Intersection Improvements* (unpublished). Auckland.