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# Exploring the safety impacts of bus lanes

Lorelei Schmitt,[1] James Wratt[2]
[1]NZ Transport Agency Waka Kotahi, Wellington, New Zealand
[2]Auckland Transport, Auckland, New Zealand
Email for correspondence: Lorelei.Schmitt@nzta.govt.nz

## Abstract

Bus lanes can enhance the appeal of public transport by improving service reliability and making travel times more competitive with other modes of transportation. While these benefits are well recognised, the road safety impacts of implementing bus lanes are less clear. This paper reviews literature on the safety impacts of bus lanes, revealing instances where their implementation has led to a reduction in crashes or certain types of crashes (e.g., severe). However, the review also highlights cases where crashes have increased following the introduction of bus lanes. Adding to research in this area, high level analysis of three corridors in New Zealand are presented. A discussion of trends and contributing factors is offered to provide recommendations for the planning, design, and operation of bus lanes that are most likely to contribute to safe system outcomes.

## 1 Introduction

There is a mix of outcomes documented in research on the effects of introducing bus lanes, with some cases showing an increase in the volume of crashes, albeit not necessarily the severity (Felix 2022). Meanwhile other research has found decreased number of crashes and reduced crash severity. For example, Goh and Currie (2013) studied crash data for bus lanes in Melbourne, Australia and found that they reduced crashes, with a statistically significant reduction of 18%.

The present paper adds to this area of research by providing a review of literature on this topic. High level before and after trends are explored along with documentation on aspects of contexts or designs that have been found to be associated with increased or decreased crashes, or severity of crashes.

The paper further adds to this body of literature by exploring three corridors in New Zealand where bus lanes have been introduced relatively recently. Crash statistics are observed from before and after the introduction of bus lanes.

The implications of the full body of research are then discussed to provide a series of practical recommendations for transport planners, engineers and policy makers to ensure best practice in the planning, design, and operation of bus lanes that are most likely to contribute to safe system outcomes.

## 2 Literature

A range of research exists in this domain from across the globe. It is important to note that the context for different bus lanes studies varies, with some research examining full bus rapid transit (BRT) systems while other research explores more conventional bus lanes.

## 2.1 International research

One of the most useful international resources in this area is a meta-analysis of case studies of bus priority systems globally by Duduta et al. (2015). While this report largely centres on fully segregated systems it also does include more conventional bus lanes and useful analysis. The report largely focuses on research examining full BRT systems, which have found crash reduction of approximately 40% for injury crashes and 50% for fatal.

As evident in Table 1, there was a wide range in safety outcomes depending on bus priority infrastructure type. The BRT systems analysed found the highest crash reductions. This compares to bus lanes which saw mixed results - with crash reductions for bus lanes in an Australian study (18% reduction) and increases in studies from the United States. High occupancy vehicle lanes studied in the United States (known as transit lanes in New Zealand) saw a 61% increase in crashes.

**Table 1: Summary of changes in crash frequency from Dudata, et al. (2015)**

| | % change in accidents | 95% confidence interval | Source |
|---|---|---|---|
| **Arterial BRT (Latin American countries)** | | | |
| Fatalities | -47% | (-21%; -64%) | EMBARQ analysis |
| Injuries | -41% | (-35%; -46%) | |
| All crashes | -33% | (-29%; -36%) | |
| **Arterial BRT (Latin America and India )** | | | |
| Fatalities | -52% | (-39%; -63%) | EMBARQ analysis |
| Injuries | -39% | (-33%; -43%) | |
| All crashes | -33% | (-30%; -36%) | |
| **Bus priority (Australia)** | | | |
| All crashes | -18% | n/a | Goh et al. 2013 |
| **Peak-hour bus and high-occupancy vehicles (HOV) lanes (United States)** | | | |
| Unspecified severity | +61% | (+51%; +71%) | Elvik and Vaa 2008 |
| **Peak-hour bus lanes (United States)** | | | |
| Injury crashes | +12% | (+4%; +21%) | Elvik and Vaa 2008 |
| Property damage crashes | +15% | (+3%; +28%) | |
| **Permanent lanes for buses and taxis (United States)** | | | |
| Injury crashes | +27% | (+8%; +49%) | Elvik and Vaa 2008 |
| Unspecified severity | -4% | (-8%; 0) | |

The research by Duduta et al. (2015) offers a valuable compendium of road safety considerations related to bus priority. It provides a thorough analysis of how various street modifications, commonly implemented during the installation of bus lanes and full BRT systems, influence crash frequency and severity. A summary of their quantitative findings is provided in Table 2.

**Table 2: Safety impact of common infrastructure changes associated with bus priority from Dudata et al (2015).[1]**

| | Crash type | % change in crashes | 95% confidence interval |
|---|---|---|---|
| Converting a four-way intersection into two T-junctions | Severe | -66% | (-1%, -88%) |
| | All types | -57% | (-37%, -70%) |
| Removing a traffic lane | Severe | -15% | (-11%, -17%) |
| | Vehicle collisions | -12% | (-9%, -15%) |
| Shortening crosswalks (each additional meter removed) | Severe | -2% | (-0.04%, -4%) |
| | Pedestrian crashes | -6% | (-2%, -8%) |
| Prohibiting left turns on main corridors | Severe | -22% | (-12%, -32%) |
| | Vehicle collisions | -26% | (-10%, -43%) |
| Introducing a central median | Severe | -35% | (-8%, -55%) |
| | Vehicle collisions | -43% | (-26%, -56%) |
| Introducing a counterflow bus lane | Severe | +83% | (+23%, +171%) |
| | Vehicle collisions | +35% | (+0.02%, +86%) |
| | Pedestrian crashes | +146% | (+59%, +296%) |
| Reducing distance between traffic signals (for each 10m) | Severe | -3% | (-1%, -5%) |
| | All types | +2% | (+0.03%, +4%) |
| | Pedestrian crashes | -5% | (-1%, -7%) |
| Pedestrian bridge on expressway | Pedestrian crashes | -84% | (-55%, -94%) |
| Pedestrian bridge on arterial road | Pedestrian crashes | No statistically significant impact | (-23%, +262%) |

Thus, the authors attribute the following measures bus priority measures to be associated with safety benefits: fewer traffic lanes, centre medians, shorter crosswalks (pedestrian crossings), and prohibiting turns that involve crossing traffic at intersections. Contraflow bus lanes were associated with increased crashes. Interestingly, this research also found that safety impacts accounted for up to 16% of total economic benefits of Latin American BRT.

Research from Hong Kong has also found a statistically significant decrease on two corridors for bus crashes causing fatal or serious injury. But the researchers also found 5 other sites with no statistically significant changes (Tse, et al, 2012 as cited in Felix 2022)

Meanwhile, research in the United States has produced mixed findings. One study examining bus lanes in Los Angeles found that crashes increased during bus lane operating hours on all but one of the corridors studied. However, these tended to be less severe and involved a smaller proportion of pedestrians (Felix, 2022).

In Chicago, an initial spike in bus-pedestrian crashes was observed after bus lane installation. However, this was followed by a long-term decrease in both pedestrian and bus-related crashes (LaPlante and Harrington 1984 as cited in Felix 2022). Analysis of three bus lane corridors in San Francisco found a 16% reduction in total crashes and a 24% decrease in death and serious injury crashes (SFMTA 2017 as cited in Felix 2022). On another San

[1] Note that the research is from a country where people drive on the right so the table row about 'prohibiting left turns on main corridors' refers to turning across traffic (which would be right turns in New Zealand and Australia).

Francisco corridor, Mission Street, no change was observed in pedestrian and motor vehicle crashes, but bus crashes declined by 85%.

Chen et al. (2013) found that bus lanes in New York were generally associated with an increase in crashes. However, they noted that these corridors already had higher crash rates prior to the introduction of bus lanes, attributing this trend to Regression to the Mean effects. Additionally, the bus lanes were introduced without coloured surfacing and with minimal enforcement, which reduced their effectiveness and led to frequent blockages.

Other research from the United States has found that narrow lanes increase the risk of bus side impact crashes, leading to recommendations that buses operate in lanes at least 3.7m wide (Sando and Moses 2010 as cited in Hillsman and Hendricks 2012). These findings were echoed in an analysis from Austin, Texas, where Dai et al. (2021) observed similar crash patterns. Their study also highlighted that the presence of a kerb or parked car immediately adjacent to the outside lane posed safety concerns, regardless of lane width. The authors conclude that while narrower lanes may contribute to fewer catastrophic crashes due to slower speeds, they also increase the likelihood of certain types of bus crashes.

Increased crashes were observed for bus lanes across three Israeli cities studied by Gitelman et al. (2020), though these increases were not found to be statistically significant. These researchers also found centre running bus lanes to be safer than kerbside bus lanes.

Felix (2022, p.14) argues that aspects of bus lane design and implementation, “has a pronounced effect on outcomes. Installing bus lanes in the offset or centre lane, painting the lane red, reducing the number of traffic lanes, and shortening crosswalks all made streets safer”. He further contends, “The increase in collisions that most of the studied bus lane segments saw is not evidence that the bus lanes are the cause. Rather, it is evidence that bus lanes should be given thoughtful consideration when they are installed” (Felix, 2022, p.106). Additionally, his analysis found a correlation between bus lanes and a reduction in severe and pedestrian-involved collisions which he notes was not found in a ‘control corridor’ without bus lanes.

## 2.2 Australian research

As captured in Table 1, Goh and Currie (2013) undertook empirical analysis of crash data for bus lanes in Melbourne, Australia, which found bus lanes to be associated with an 18% reduction in crashes. Interestingly, their research also found the number of fatal and serious incidents to drop by 31%.

The authors also undertook disaggregate analysis using safety audits and reviewing crash types. From this they attribute crash reduction to a decrease in buses hitting stationary objects and vehicles due to less bus manoeuvring. The authors purport that bus lanes:

- serve as a roadside buffer between travelling cars and other users
- increase sight distances at unsignalised intersections
- slow traffic to safer speeds, and
- minimise bus manoeuvring.

## 2.3 New Zealand research

There is limited research in New Zealand interrogating crash trends before and after the introduction of bus lanes. However, Newcombe and Wilson (2011) examined four corridors in Auckland in terms of cycle and motorcycle crash trends to see if these modes were made more or less safe by the introduction of bus lanes. Their research found no discernible difference for three of the corridors. However, the Dominion Road corridor had a 30% increase in cycle and motorcycle crashes. The bus lanes on this corridor were much narrower than the other corridors (3.0m), and narrower than standard bus lane width recommendations (e.g.

NZTA 2023). The study team concluded that the substandard narrow lane width was the key factor leading to poorer safety outcomes.

In follow up communications one of the authors noted that squeezing bus lane widths down has several unintended consequences on safety, pavement material, capacity of adjacent lanes, pedestrian spaces and shy distances (personal communication).

### 2.4 Summary of findings

The literature reviewed covered a wide range of countries and contexts for bus lane implementation. Key findings include:

- Crash frequency and severity:
    - There were mixed results in terms of crash frequency before and after bus lane implementation, with reductions more common but not guaranteed.
    - Some studies report initial increases in crashes post-implementation, often attributed to lack of enforcement or pre-existing high crash rates. Over time, these corridors tend to show long-term safety improvements.
    - Typically, bus lanes are associated with a reduction in crash severity, and fatal crashes can decrease by up to 50%.
- BRT systems show consistent and substantial safety benefits.
- For standard bus lanes, safety outcomes are less clear, with a general trend towards reduced serious crashes but increases in overall crash numbers for some corridors.
- Aspects of design and operation of bus lanes that can influence safety outcomes include lane widths, lane position (e.g. centre running vs kerbside), number of general traffic lanes, pedestrian crossing lengths, coloured surfacing, and enforcement.

These insights highlight the importance of well-designed bus lanes and the potential for safety improvements when implemented effectively.

## 3 High-level analysis of recent New Zealand bus lanes

Bus lanes have been incrementally added to New Zealand's transport network over time. Three corridors in Auckland which have relatively recently had bus lanes installed were selected for high-level examination to provide additional insights on the safety impacts of bus lanes.

### 3.1 Method

New Zealand has a Crash Analysis System (CAS) in which all reported road crashes are recorded. High level insights were developed by using chi-square analysis to compare reported crashes for a 5-year period before and a 5-year period after each of the three bus lanes were developed.

It should be noted that due to the limited number of corridors available to study the following caveats are relevant to the method:

- the "after" period also includes the period of construction and
- will include some periods of covid pandemic related lockdowns which was correlated with lower vehicle kilometres travelled.

Chi-square analysis was undertaken twice for each corridor. First, the total number of crashes were compared using chi-square. Then, chi-square analysis was repeated with a simple 'weighting' applied to the crashes based on severity:

- Non-injury crashes were valued as 1
- Minor crashes were valued as 2

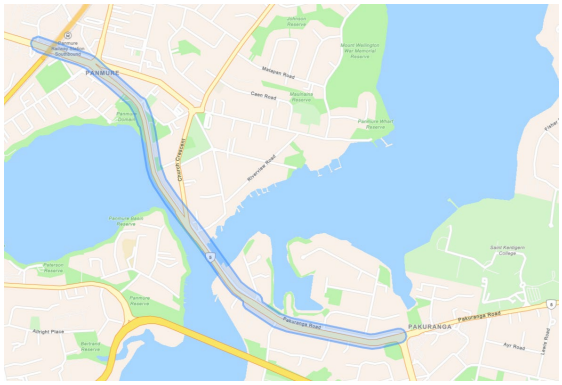
- Serious crashes were valued as 3
- Fatal crashes were valued as 4.

This weighting was selected to provide a simple way of exploring the value of changes in different severity levels of crashes before and after the changes.

## 3.2 Eastern Busway, Auckland

As part of the Eastern Busway project, Auckland Transport has installed 2.6 km of bus lanes along Lagoon Drive and Pakuranga Road.

**Figure 1: Section of the corridor analysed in CAS**




Construction began in April 2019, and the busway officially opened in December of 2021. Note that during construction temporary speed limits were applied in some sections of the corridor as part of the temporary traffic management. Also note that during this time the permanent speed limit of the corridor was reduced from 60 km/h to 50 km/h. In 2025 this was reversed to 60 km/h.

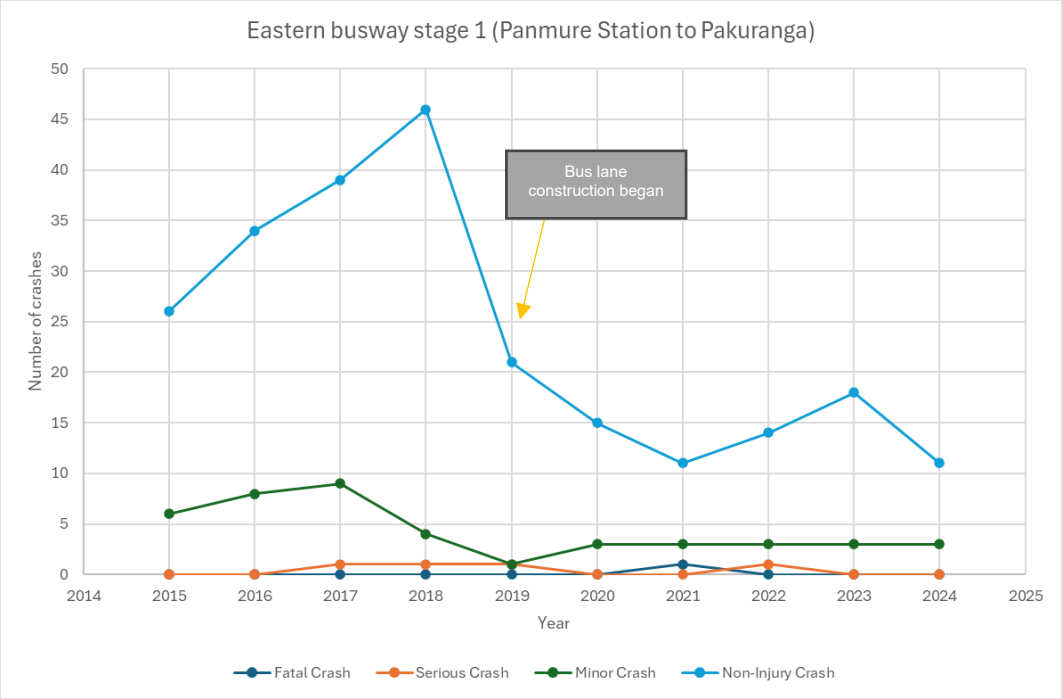
Prior to the busway much of the road was a standard 4-lane arterial road with 2 traffic lanes in each direction and a footpath (Figure 2). As part of the busway development the road was transformed to have physical separation in the middle: on one side a bus corridor was built with one bus only lane in each direction (side-running). On the other side of the physical divider general traffic is accommodated (Figure 3). A separated active modes corridor was developed. The bus lanes are operational at all times.

**Figure 2: Lagoon Drive before the busway was developed. (Source: Google Streetview)**

**Figure 3: Lagoon Drive after the busway was built, view from the active modes corridor, the general traffic lanes are on the far side of the vantage. (Source: Google Streetview)**

There were 197 crashes recorded in CAS between 2015-2019. Meanwhile 86 crashes were recorded between 2020 – 2024. With construction beginning in April 2019, both periods will include some construction, though the latter period would include a greater share of construction period. Numbers of crashes are presented by year in the figure below.

**Figure 4: Crashes by severity for each year**

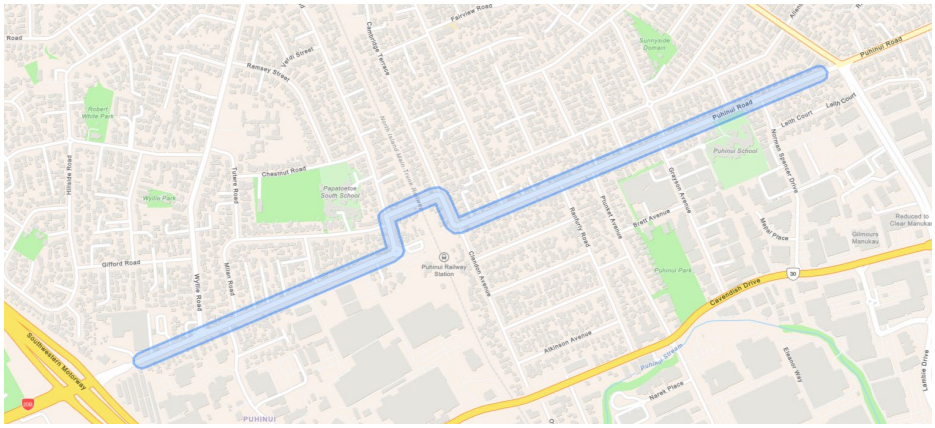



The results indicate a lower number of total crashes, with the results particularly pronounced for non-injury and minor crashes. Chi-square tests revealed that this difference was statistically significant for total crashes $\chi^2(1, N=283) = 43.5$ $p<.05$ and when weighted for crash severity $\chi^2(1, N=337) = 46.4$ $p<.05$, with a slightly larger effect size for the latter.

## 3.3 Puhinui Road bus lanes, Auckland

Bus lanes have been installed along 2 km of Puhinui Road to enhance access to Auckland Airport and improve overall public transport efficiency as part of the short-term Airport Access Improvements project and the long-term Airport to Botany Mass Rapid Transit project.

**Figure 5: Section of the corridor analysed in CAS**



Construction began in October 2020, and the bus lanes began operating in May 2021.

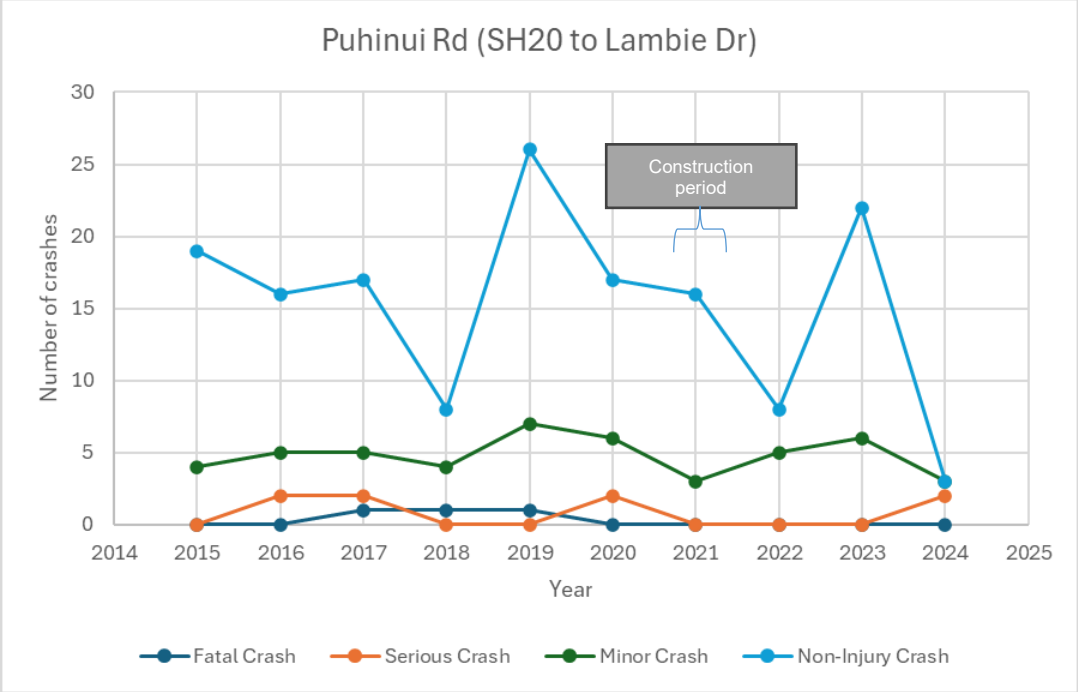
Prior to the bus lane implementation, a typical corridor cross section included one traffic lane in each direction plus an on-road cycle lane and a wide flush median Figure 6. This was converted to a 4-lane road with one bus lane and one general traffic lane in each direction with no central median (Figure 7). A shared path was developed on one side of the corridor. The bus lanes are operational from 6am-7pm.

**Figure 6: Puhinui Road before the bus lanes were implemented. (Source Google Streetview)**

**Figure 7: Puhinui Road after the bus lanes were implemented. (Source Google Streetview)**

There were 118 crashes recorded in CAS between 2015 – 2019. Meanwhile 93 crashes were recorded between 2020 – 2024. The construction period October 2020 – May 2021 occurred entirely in the second period. Numbers of crashes per year are presented by severity in the figure below.

**Figure 8: Crashes by severity for each year on Puhinui Road**




The results indicate a slightly lower number of total crashes and no fatal crashes after the bus lanes were implemented (compared with three before they were implemented). Chi-square tests revealed that the difference for total crashes was *not* statistically significant $\chi^2(1, N=211) = 2.96$ $p>.05$.

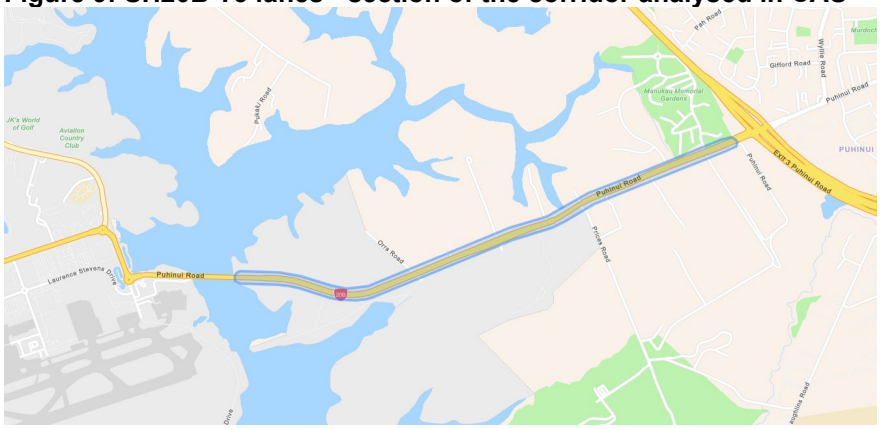
When weighted for crash severity, $\chi^2(1, N=284) = 4.56$ $p<.05$, indicating that the change in crash severity along with frequency was statistically significant, though the effect size was not large. This finding likely relates to the reduction in fatalities, which are weighted four times greater than a non-injury crash under this method. However, it should be noted that three fatalities are not a large number of incidents statistically speaking.

## 3.4 SH20B T3 transit lanes, Auckland

High occupancy vehicle transit lanes (T3) have been installed on another section of Puhinui Road, where it transforms into state highway 20B (rather than being an urban arterial). This

project involved road widening, resurfacing, and drainage enhancements to accommodate new transit lanes, as well as improvements for walking and cycling.

**Figure 9: SH20B T3 lanes - section of the corridor analysed in CAS**




Construction began in January 2020 and the project was completed in April 2021. The speed limit of this corridor prior to construction was 100 km/h. This was reduced to 60 km/h on project completion.

The was transformed from a two-lane road in each direction with shoulders (Figure 10) to a 4-lane road which included a T3 lane in each direction, a wire rope barrier in the median and an active modes shared path (Figure 11).

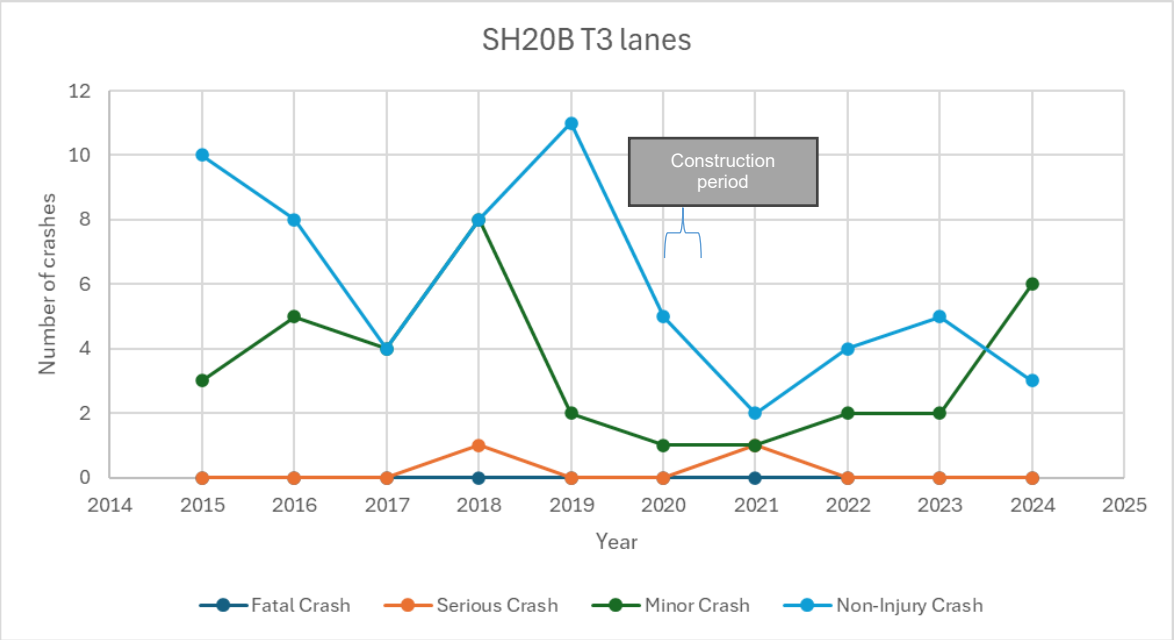
The T3 lanes are reserved for vehicles with 3 or more occupants (including buses) and are operational at all times.

**Figure 10: SH20B before the T3 lanes. (Source Google Streetview)**

**Figure 11: SH20B after T3 lanes and active modes improvements. (Source Google Streetview)**

There were 64 crashes recorded in CAS between 2015 – 2019. Meanwhile 32 crashes were recorded between 2020 – 2024. The construction period, January 2020 – April 2021, occurred entirely in the second period. Numbers of crashes per year are presented by severity in the figure below.

**Figure 12: Crashes by severity for each year on SH20B**




The results indicate half as many total crashes during and after the T3 were implemented. Chi-square tests revealed that the difference for total crashes was statistically significant $\chi^2(1, N=96) = 10.67$ $p<.05$.

When weighted for crash severity, $\chi^2(1, N=134) = 13.16$ $p<.05$, indicating a larger effect size once crash severity was considered along with frequency.

## 3.5 Summary of results

In summary, the results of the high-level analysis of Auckland corridors yielded the following findings.

**Table 3: Auckland corridor analysis findings**

| Location | Infrastructure description | Changes in total crash frequency | Changes in crash frequency (weighted by severity) |
|---|---|---|---|
| **Eastern Busway** | Installed BRT through mix of corridor widening and conversion of general traffic lanes. | Significant crash reduction, large effect size | Significant reduction, larger effect size |
| **Puhinui Road** | Converted from 2-lane road with cycle lane and flush median to 4-lane road with bus lanes and general traffic lanes | Slight reduction, but not significant | Significant reduction, small effect size |
| **SH20B** | Converted from 2-lane road with shoulders to 4 lanes (2 general traffic, 2 Transit lanes) | Significant reduction, moderate effect size | Significant reduction, slightly larger effect size |

Thus, all examined corridors showed a decrease in total crashes, although this reduction was not significant in one corridor. When weighted for severity, all three corridors experienced a significant reduction with the most pronounced results observed for the segregated busway.

# 4 Discussion

The literature review explored a variety of international research examining road safety outcomes after bus lanes were introduced. This review found that while there are instances where the frequency of crashes increased after bus lanes were implemented, the general trend is for some decline in crash frequency, particularly in the severity of crashes.

The research also highlighted several factors associated with bus lane implementation that can help reduced crashes, especially serious ones. These factors include:

- higher level of segregation (e.g. busway vs shared corridor bus lanes)
- centre running bus lanes
- bus lane widths of 3.7m or more
- coloured surfacing
- shorter pedestrian crossing distances
- enforcement.

Complementary measures that often accompany bus lane implementation such as prohibiting turning movements, intersection upgrades, median treatments (e.g., flush medians or barriers), provision of high-quality separated facilities for people walking and/or cycling, and general road upgrades like resurfacing or drainage improvements, have also been found to support reduced crashes.

That said, there is still somewhat limited research on the subject matter. The most comprehensive resource focuses on BRT, which is still much less common in New Zealand than standard bus lanes. To address this shortage of research, we undertook an examination of three corridors in New Zealand.

Generally, the high-level analysis of the three Auckland corridors yielded results that were consistent with existing literature related to the safety impacts of bus lanes. There was a general trend for absolute crash reduction, especially for more severe crash types, though this trend was stronger for the busway as seen by the larger effect sizes.

As part of the development of these corridors' bus lanes several complementary components were included that may have contributed to the safety outcomes such as:

- All corridors included improvements for active modes with dedicated off-roadway infrastructure.
- Barriers were added to the SH20B corridor, and the Eastern Busway design had the bus lanes and active modes infrastructure fully segregated.
- New signalised intersections on SH20B.
- Permanent or temporary speed limit changes, for example SH20B was reduced from 100km/h to 60km/h.
- Road resurfacing and drainage improvements.

While it is not clear what level of contribution these features may have had to the safety outcomes, it is noted that stronger effect sizes were observed on corridors with physical separation in the medians. This is consistent with the research by Dudata et al. (2015) which documented a 43% reduction in collisions, including a 35% reduction in severe crashes, associated with introducing a central median.

## 4.1 Limitations

While the case studies presented offer some useful high-level insights, there are some noteworthy research caveats to consider.

### 4.1.1 Corridor selection

Finding appropriate corridors to examine was challenging. Several corridors were first considered for examination, but were then dismissed, often due to:

- Timing of construction: Many corridors initially considered for analysis had bus lanes installed only within the last five years, resulting in insufficient data for drawing conclusions.
- Incremental public transport priority improvements: Many corridors undergo incremental public transport priority improvements before bus lanes are installed. For example, a road may transition from full-time parking on one side to part-time parking with a clearway during certain hours, and eventually to a bus lane. Alternatively, a lane might operate as a 'transit' lane (high-occupancy vehicle lane) before becoming a bus lane. The safety impacts of these interim treatments are not well understood and warrant further research.

Due to these challenges, we accepted 'imperfect' corridors for study, which included periods of construction and COVID-19 lockdowns. Thus, the ‘after’ time periods analysed may have included changes in crash statistics that were actually associated with construction activities, such as road diversions and temporary speed limits.

The observed crash reductions in 2020 and 2021 might also be, in part, related to reduced travel to during COVID-19 lockdowns, especially near the airport as some air travel was quite limited.

Therefore, additional analysis of the corridors, once they have been in place longer and can exclude the COVID-19 and construction years, would be beneficial.

### 4.1.2 Method

Due to limited resources, we were only able to undertake high-level analysis. While this still provides a useful contribution to the limited body of research, we acknowledge that the research could be even more informative and robust by:

- Comparing observed crash reductions with ‘control’ sites to understand underlying crash trends.
- Applying more complex analysis of disaggregate variables such as causes (e.g. alcohol), and crash types by year.
- Sophisticated analysis to better interrogate the relative role of bus lanes (including different types) and complementary changes to infrastructure (e.g. cycle paths) and traffic management (e.g. speed limits) to observed safety outcomes.
- Conducting more detailed analysis of crash severity types. We considered alternative valuations for the weightings, such as:
    - the social cost per injury listed in the NZTA Monetised benefits and cost manual[2] or
    - calculating Death and Serious Injury (DSI) equivalents[3].

These methods were considered but not adopted for justifiable reasons. Using the social injury costs would have been relatively straightforward, but these figures are intended for economic analysis, which was not the primary intent of this study. It is likely they would have made the effect sizes quite a lot stronger given that the fatality value ($12,500,000) is 184 times a minor injury ($68,000).

Calculating DSI equivalent factors would be particularly useful for crash prediction in the corridors but was dismissed in this instance due to time and complexity required.

[2] https://www.nzta.govt.nz/resources/monetised-benefits-and-costs-manual/

[3] Calculating DSi equivalents | NZ Transport Agency Waka Kotahi

# 5 Recommendations

This research paper offers useful insights that can improve the planning, design and operations of potential bus lanes.

## 5.1 Planning

In considering public transport priority projects the potential safety benefits of bus lanes should be considered. Whilst not all the research found crash reduction there was more often a reduction in crashes and usually in the severity of crashes. The results indicate that well-designed bus lanes can have benefits beyond more efficient bus trips in the form of safer streets.

Since the literature review was initially undertaken, it was used to inform an update to the advice in the NZ Transport Agency Waka Kotahi Crash estimation compendium: New Zealand crash risk factors guidelines (NZTA 2024). The guidance formerly instructed a crash modification factor of 1.25 (though acknowledged a low level of confidence). This applied a crash penalty, basically predicting that implementation of a bus lane (with taxis permitted) might be reasonably expected to result in a 25% increase in crashes. This value has since been changed to a neutral 1.0 value and commentary has been added on design features that might lead to a more promising crash modification factor (Figure 13).

**Figure 13: Updated advice on bus lanes in the NZTA Crash compendium. (Source NZTA, 2024)**

| Common Urban Midblock Crash Reduction/Modification Factors | | | | | |
|---|---|---|---|---|---|
| **Treatment** | **Sub type** | **Crash Reduction Factor** | **Crash Modification Factor** | **Confidence** | **Comment** |
| | New lighting - railway level crossing (NEW) – V4 to V1 | 20% of night-time crashes | N/A | High | |
| Traffic calming | All environments | 20% | 0.8 | Medium | Where available use CMFs and CRFs that are specific to each treatment used in traffic calming. |
| Bus lanes (taxis permitted) | All | 0% | 1.00 | Low | Research indicates that crashes can increase or decrease with the introduction of bus lanes depending on design. Design elements that can reduce crashes associated with bus lanes include:<br>• Bus lane positioning (centre running tends to be safer than kerbside)<br>• Wider lanes<br>• Limiting right turns along corridor<br>• Install centre median strips or pedestrian island on corridor<br>• Controlled pedestrian crossing facilities<br>• Enforcement of bus lanes – otherwise buses change lanes to get around people blocking bus lanes (e.g. standing cars) which can create a conflict<br>A specific CMF can be developed in response to adopting crash-mitigation measures. |
| High occupancy vehicle lanes | All | 60% increase | 1.60 | Low | There is no Australasian research available on this treatment. This risk may be mitigated by suitable design. |

With the present paper's addition of the three corridors studied, the above advice could potentially be further modified to suggest a beneficial, rather than neutral, crash modification factor. Another option would be to provide disaggregate crash modification factors based on design features like bus lane widths and the position of bus lanes (e.g. centre running or kerbside), as the literature review indicated these were the greatest factors in predicting crash types.

## 5.2 Design

Given the literature review found different design components to be associated with safety outcomes, design guidance and other resources can be modified to best support inclusion of crash reducing features (e.g. coloured surfacing, safer lane widths, medians, prohibited turns, shorter crossing distances). Similarly, guidance should be updated to clearly articulate key

issues to avoid (e.g. substandard lane widths, particularly where bus lanes will be shared with vulnerable users and no dedicated separated cycling infrastructure will be provided).

## 5.3 Operations

The research revealed that operational elements of bus lanes can significantly impact safety outcomes. For example, the literature review indicated that a lack of enforcement can be problematic not just from a bus operations perspective but also can contribute to worse safety outcomes (Chen et al 2013).

## 5.4 Monitoring

The literature review revealed that the safety impacts of bus lanes are not well documented. Given the varied road safety outcomes associated with bus lane implementation, it would be beneficial for the transport sector if councils or other organisations undertook more comprehensive before-and-after monitoring of corridors when major changes, such as bus lane implementation, occur. Careful documentation of these changes will contribute to a broader understanding within the sector of the influence of different road features (e.g. bus lane widths), leading to more effective and pragmatic best practice guidance.

## 5.5 Further research

This research indicated ample opportunity for further research to build the knowledge base in this domain. Similar studies looking at before and after crash statistics for corridors would be worthwhile. The method used in this paper could be strengthened by doing more detailed analysis of crash types and features with robust statistical tests that allow for a larger range of variables.

The present analysis could potentially be repeated using different weighting valuations as discussed in the literature review, particularly to explore economic impacts or crash prediction effects associated with bus lane street changes.

It would be promising to re-examine the corridor analysis in the future when the construction period and COVID-19 time periods can be isolated out of the data.

The current NZTA Crash compendium guidelines shown in Figure 13 above includes a relatively high ‘penalty’ for ‘transit’ lanes. This advice is consistent with research by Elvik and Vaa (2008) as documented in Dudata et al (2015) which found a 60% increase in crashes with peak hour bus and high occupancy vehicles lanes in the US.

Transit lanes were not fully examined in the wider literature review, however. The SH20B case study did include transit lanes and found significant crash *reduction* in terms of both frequency and severity of crashes. However, there were several other changes made to this corridor in terms road widening, provision of dedicated active modes infrastructure and median barrier installation which could be affecting the positive safety outcomes. Given the conflicting findings, this type of street change warrants further exploration. Also, where buses stop frequently it seems reasonable that there would be issues with weaving if the lane was not segregated from general traffic lanes. This would be particularly useful as transit lanes are often implemented as an interim treatment before bus lanes.

Additionally, operations that give buses greater priority in bus lanes, such as through signal priority would be interesting to interrogate further in terms of road safety outcomes.

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