Measuring Pedestrian Delay

Final Report

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Table of Contents

List of Figures

1 Introduction

The purpose of this report is to quantify pedestrian delay at signalised intersections in the Auckland city centre, which are a significant contributor to delays and inconvenience experienced by people walking in the city centre. Our methodology is based upon the NZ Transport Agency's (2016) *Economic Evaluation Manual*, which provides guidance on valuing travel time delays incurred by transport users, regardless of mode of travel.

The results in this report can be compared with estimates of the cost of congestion for other road users (ie people in cars or buses). This methodology could also be extended to identify the effect of changes to intersection signal timing on pedestrian delay, which could contribute to a holistic assessment of the effects for all road users, including people in buses, cars, and on foot.

1.1 The context for this analysis

There is a direct connection between how we measure congestion and the resulting strategies for addressing congestion. Any proposed transportation and public realm project must assess the implications that the project would have on congestion prior to implementation. Typical methods for measuring congestion focus strictly on roadway delay. Thus, any subsequent response to either decreasing or augmenting congestion addresses just one aspect of the street: car delay at signals. Other modes (pedestrians and cyclists) are rarely considered when weighing up the costs or benefits of a project or strategy. This can lead to signal timing and road design that overwhelmingly favours car through movement at the expense of pedestrians.

These methods have persisted largely due to ease with which motorised traffic data can be captured and modelled. It is difficult to automate data capture for pedestrians, and still more difficult to model their behaviour. While there are some instances of pedestrian counting in the city centre (Heart of the City), the existing data is largely focused around private vehicles and public transport.

The delay associated with traffic congestion is often translated to a monetary value using an estimation of the value of users travel time. In New Zealand, estimations of the cost of delay have ranged from $250 million to $1.25 billion. Because walking counts are sporadic, there are no equivalent methods for assessing lost productivity associated with pedestrian delay. This renders a comparison of economic costs and benefits of pedestrian delay and traffic delay impossible.

And yet, pedestrians in the city centre are an increasingly vital aspect of movement in Auckland's city centre. Auckland's city centre is one of New Zealand's key business centres accounting for around 13%[1] of Auckland's employment and 7.4% of New Zealand's overall economic activity. It is home to two universities, which attract approximately 36,700 students daily. The city centre is also home to a significant residential population, 40,000 people, over half of whom walk for their commute. This residential population has risen dramatically in the past 3 years, with an additional 12,000 residents joining the core city centre population. This results in large pedestrian volumes throughout the day on both weekends and weekdays. On some city centre streets, pedestrian volumes are significantly larger than traffic volumes (see Table 1).

Table 1: Pedestrian volumes and vehicle volumes on selected city centre streets

Street	Average daily pedestrian count (2016)	Average 7-day daily traffic count	Ratio of pedestrian counts to vehicle counts
210 Queen St [Sum with 205 count?]	36,272	9,989 [March 2016; between Victoria St and Darby St]	3.63
107 Quay St	22,940[2]	22,823 [February 2016; between Commerce St and Gore St]	1.00

[1] Source data from http://www.stats.govt.nz/browse_for_stats/businesses/business_characteristics/BusinessDemographyStatistics_HOTPFeb15/Commentary.aspx

[2] Due to pedestrian counters being located only one side of the street, this is a doubling of the average pedestrian daily count for these two locations. Traffic counts include both directions of traffic in their estimations.

Street	Average daily pedestrian count (2016)	Average 7-day daily traffic count	Ratio of pedestrian counts to vehicle counts
59 High St	16,842[2]	1,273 [April 2013; between Courthouse and Durham St]	13.23
Karangahape Rd (150 and 183 K Rd)	15,298	17,923 [October 2013; between Upper Queen St and Pitt St]	0.85

Traffic count data from: https://at.govt.nz/about-us/reports-publications/traffic-counts/

See also: http://www.trafficcounts.co.nz/

Ensuring an accurate comparison between modes becomes imperative in the city centre when determining signal strategies and street designs, where both space is limited and pedestrian volumes outweigh car volumes. This report outlines a methodology to quantify the delay that pedestrians experience to better inform design decisions.

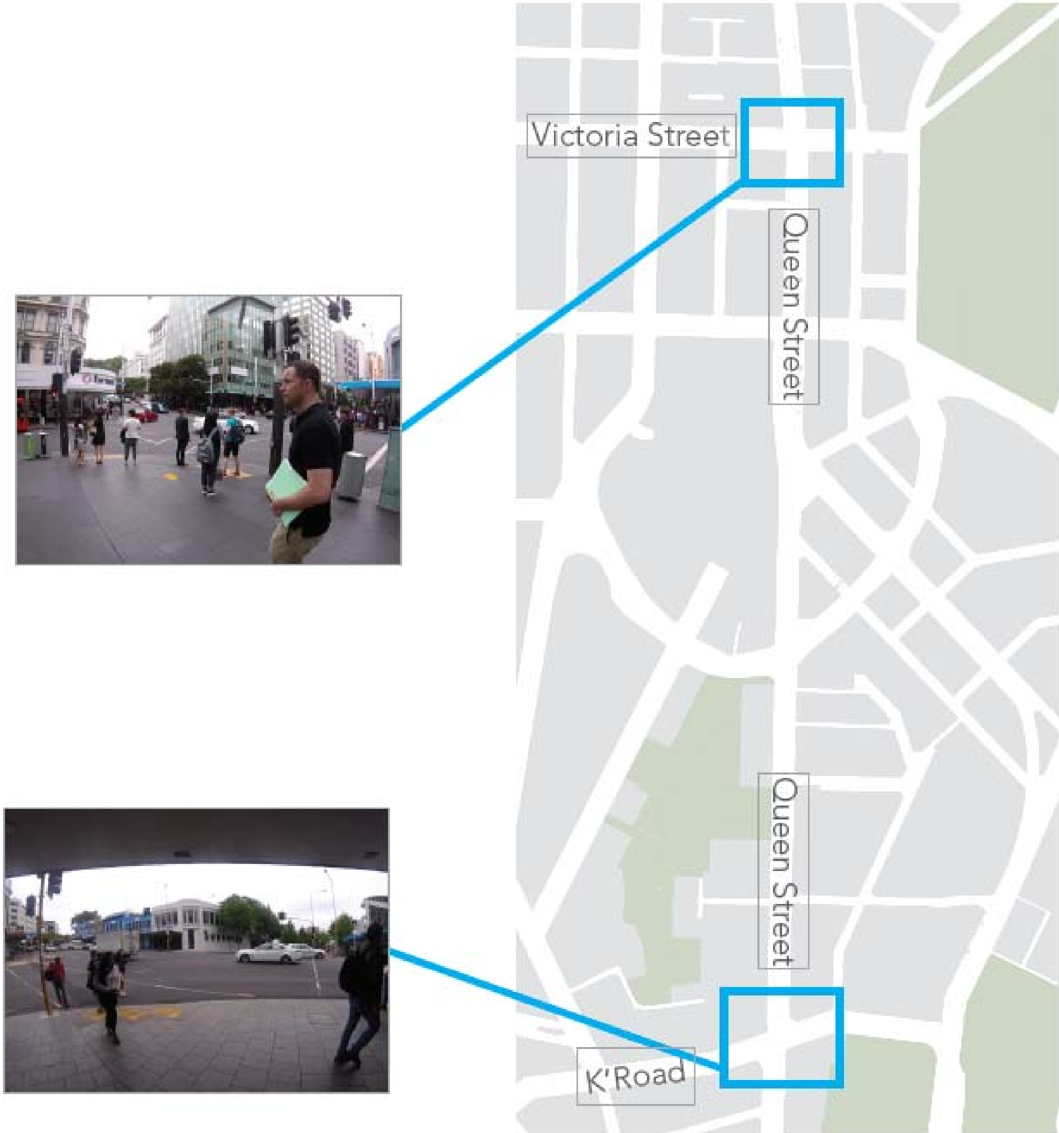
1.2 Selected case studies

To illustrate the feasibility of quantifying pedestrian delay, we have undertaken case studies of pedestrian delay at two busy intersections in the Auckland city centre:

- The intersection of Victoria Street and Queen Street, which is a Barnes Dance intersection which allows pedestrians to cross the intersection diagonally; and
- The intersection of Upper Queen St and Karangahape Rd (K'Road), which has two pedestrian phases coinciding with traffic movements.

These intersections were selected due to the fact that they have relatively high pedestrian volumes and different characteristics in terms of signal timing. Figure 1 identifies the location of these intersections and illustrates their context and midday traffic volumes.

Figure 1: Case study intersections in the Auckland city centre



1.3 Structure of this report

This technical report includes two sections:

- Section 2 describes our methodology for calculating the cost of pedestrian delay at intersections and summarises the data we used to implement this methodology.
- Section 3 reports the results of this evaluation, places them in context, and briefly discusses the implications for transport network planning and management in the Auckland city centre.

2 Methodology and data

In this section, we describe our methodology for measuring pedestrian delay at signalised intersections, where pedestrians must wait prior to crossing the street. It provides:

- An overview of the key steps in our analysis;
- A description of the data we used to undertake this analysis; and
- An overview of caveats to this analysis.

2.1 Key steps in analysis

Our methodology involves five key steps.

Step 1: Measure pedestrian movements through the intersection

In order to understand how intersection timing affects the delays experienced by pedestrians, it is necessary to know:

- How many people are arriving at the intersection in a given time period; and
- Whether and how they cross the intersection.

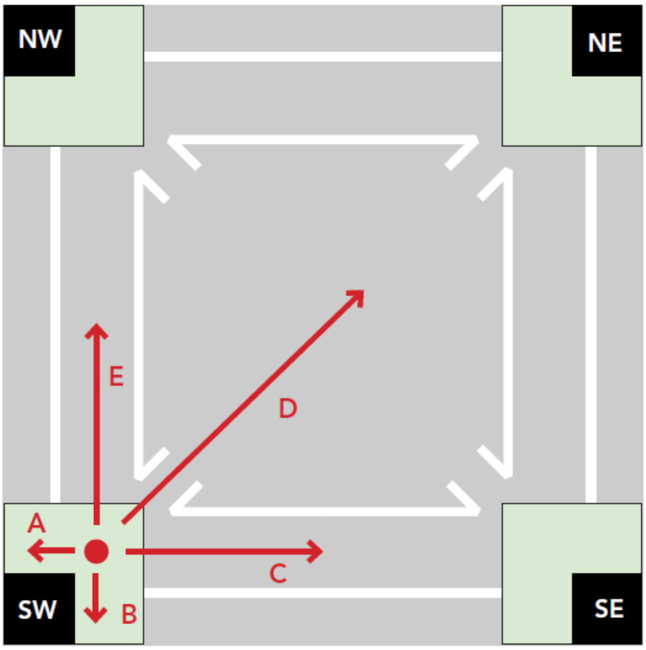
Step 1 focuses on measuring pedestrian volumes and pedestrian movements across the intersection. In this analysis, we have undertaken a count based on video recordings of these intersections during the defined time period for analysis. Surveyors were assigned to count pedestrian volumes and direction of movement through intersections.

Figure 2 shows how pedestrian movements for people arriving at the southwest (SW) corner of an intersection were classified for analysis. Once a person has arrived at the corner of the intersection, there are five main things that they could do:

- Movements A and B: Turn the corner, incurring no delay at the intersection.
- Movement C: Cross towards the southeast (SE) corner of the intersection, which would require them to wait for a single walk signal.
- Movement D: Cross towards the northeast (NE) corner of the intersection. At a Barnes Dance this would mean waiting for the walk signal. At other types of intersections this would entail crossing to either the north or the east first, and then waiting for a signal to cross the other leg of the intersection.
- Movement E: Cross towards the northwest (NW) corner of the intersection, which would require them to wait for a single walk signal.

Pedestrian movements C and E can be grouped for Barnes Dance intersections, as people crossing the intersection in these directions will experience the same level of delay. Movement D for Barnes Dances will have a slightly longer wait time due to a slightly longer crossing distance.

Figure 2: Summary of possible movements across an intersection



Step 2: Estimate the average delay for each pedestrian movement

Next, we estimate the average waiting time per pedestrian for each movement across the intersection using signal timing data or other relevant data. This implicitly compares current signal timing against free-flow conditions in which pedestrians would experience no delays crossing intersections, eg in a shared space-type environment. It is therefore similar to estimates of the cost of traffic congestion that compare observed peak traffic speeds against free-flow speeds (Wallis and Lupton, 2013). However, a second approach would be to compare current signal timing against signal timing that was optimised for pedestrian movements, which would tend to produce a lower estimate of delay costs.

In order estimate average delay, we assume that pedestrian arrival at the intersection is uniform throughout the time period – ie a similar number of pedestrians arrive at the intersection in each small window of time. This reflects the fact that pedestrian arrival times are influenced by a range of factors, such as the location of exits onto the street, signal timing at other intersections, variations in peoples' walking speed, window shopping, etc – that result in random arrival times.

Based on this assumption, we can estimate delay for the average pedestrian based on the relative length of pedestrian crossing phases and traffic phases. There are three things that might occur when a pedestrian arrives at an intersection:

- If they arrive during the traffic phase, they must wait for the next pedestrian phase
- If they arrive during the pedestrian phase, with enough time to safely cross before the lights change, they experience no delay
- If they arrive near the end of the pedestrian phase, with too little time to safely cross, they must wait for the lights to complete a full signal.

For a Barnes Dance intersection, we can calculate the average delay per pedestrian crossing the intersection using the formula in Equation 1. This estimates average delay based on the relative length of the traffic phase (T_C), pedestrian phase (T_P), and the minimum time required to safely walk across the intersection (T_S). Assuming that pedestrian arrival at the intersection is uniformly distributed means that we can:

- Estimate the share of people arriving in the traffic phase and pedestrian phase based on the relative length of each phase – ie if the traffic phase is three times longer than the pedestrian phase, it would indicate that three times as many people arrive during the traffic phase.

- Estimate the average delay for pedestrians arriving in the traffic phase based on the length of the traffic phase – ie the average delay for people arriving in this phase is equal to half the length of the signal phase.[3]

Equation 1: Average pedestrian delay at a Barnes Dance intersection

$$\text{Delay} = \frac{T_C}{T_C+T_P}*\frac{T_c}{2}+\frac{T_P\text{-}T_S}{T_C+T_P}*0+\frac{T_S}{T_C+T_P}*\left(\frac{T_S}{2}+T_c\right)$$

For each intersection, T_C and T_P are estimated based on signal timing data. T_S is assumed to be equal to 15 seconds (0.25 minutes) based on the average walking speed of 80 metres/minute and the average street width of around 20 metres.[4] We have generalised this approach to address other types of intersections where people crossing in different directions incur different amounts of delay.

Equation 2 demonstrates how this equation is used to calculate average pedestrian delay for a hypothetical intersection with an 80-second traffic phase (T_C=80) and 40-second pedestrian phase (T_P=40). Under these assumptions, the average pedestrian crossing this intersection is expected to experience 37.6 seconds of delay.

Equation 2: Estimation of average pedestrian delay for a hypothetical Barnes Dance intersection

$$\text{Delay} = \frac{80}{80+40}*\frac{80}{2}+\frac{40\text{-}15}{80+40}*0+\frac{15}{80+40}*\left(\frac{15}{2}+80\right)=\frac{2}{3}*40+\frac{5}{24}*0+\frac{1}{8}*87.5=37.6s$$

Step 3: Combine these results to estimate total pedestrian delay during the selected time period

In this step, we combine results for Steps 2 and 3 to estimate the total delay, in minutes, for pedestrians using the intersection during this time period. This is a straightforward calculation: the number of pedestrians crossing the intersection in this direction is multiplied by the average wait time for those pedestrians, and then results are summed up across all directions of movement.

Equation 3 describes how these results are aggregated up across the five different types of movement across the intersection. For each movement i, the number of people crossing in that direction (N_i) is multiplied by the average delay for that movement (D_i). People who do not cross the intersection – ie those who simply turn the corner at the edge of the intersection – experience zero delay.

Equation 3: Total delay for pedestrians crossing the intersection in given time period

$$\text{Total delay} = \sum_{i \in M} N_i * D_i$$

Step 4: Convert total pedestrian delay into a monetary equivalent

After estimating the total delay experienced by pedestrians during the selected time period, we convert this to a monetary equivalent using the NZ Transport Agency's (2016) estimate of the value of travel time for pedestrians during the appropriate time period. This parameter reflects the perceived value that people place on marginal changes in travel time. We explain how we have estimated an appropriate value of travel time in the following sub-section.

Step 5: Convert results to an annual estimate of the cost of pedestrian delay

Finally, as these results relate to a specific time period on the day on which data was collected, it is necessary to convert them to an annual estimate of the cost of delay. In order to do so, we scale up our estimate of cost of delay using data on how pedestrian volumes vary by time of day and between months in the same year.

Equation 4 explains how we have derived annualisation factors based on pedestrian counts. We estimate intersection-specific annualisation factors based on pedestrian counts at the nearest pedestrian count point, as the relative volume of pedestrians at different time periods may differ between locations.

This approach captures two key sources of variation:

[3] For instance, if the traffic phase is two minutes long, there will be approximately the same number of pedestrians arriving at the start of the phase (hence incurring close to two minutes' delay) as at the end of the phase (hence incurring close to zero delay).

[4] However, survey data shows that some people continue crossing even after this window, often running across the intersection. This is itself an indication that current signal timing is inconvenient for pedestrians, as they would prefer to run or expose themselves to crash risk than wait for the signal to cycle.

- Variations in pedestrian demands between different times of the day; and
- Variations in pedestrian demands between different months of the year.

Equation 4: Deriving annualisation factors for pedestrian delay

$$\text{Annualisation factor} = \frac{\text{Annual pedestrian counts}}{\text{Pedestrian counts during selected time period}}$$

In principle, it would be possible to modify annualisation factors to reflect differences in signal timing between different time periods, or variations in the composition of trip purposes between time periods. Due to limited variations in signal strategies, differences in signal timing during the day were not included.

The monetised estimates of pedestrian delay calculated in Step 4 were multiplied by annualisation factors to estimate the annual value of pedestrian delay.

2.2 Data used in analysis

We used four key sources of data to implement this analysis:

- Survey data on pedestrian movements across the two selected intersections that was collected from noon to 1pm on Wednesday 8 February 2017 – this was used to implement Step 1 of the analysis;
- Data on average signal timing at the selected intersections provided by Auckland Transport – this was used to implement Step 2 of the analysis;
- Heart of the City pedestrian count data on an hourly basis for the 2016 calendar year and the 2017 year to date – this was used to implement Step 5; and
- The NZ Transport Agency's (2016) estimates of travel purpose and value of time, which were used to estimate an appropriate value of travel time for pedestrian movements in the city centre.

Table 2 summarises survey data on pedestrian movements at the two selected intersections. Figure 3 and Figure 4 show the directional movement for both intersections. In these figures the arrows are to scale and refer to the total number of pedestrians going in either direction from the two points. Additionally, each arrow is labelled with the total number of pedestrians. The percentage marks the share of all crossing movements (excluding A/B movements).

Table 2: Pedestrian movements at two selected intersections (survey data)

Pedestrian movement	Victoria Street / Queen Street	Upper Queen St / Karangahape Rd
Intersection type	Barnes Dance	Two phase
Number of people who:		
Do not cross	2,020	702
Cross intersection (all movements)	5,677	1,190
Cross one leg	4,416	1,055
Cross diagonally/2 legs	1,261	135

Figure 3: Pedestrian Movements at Upper Queen Street / Karangahape Rd

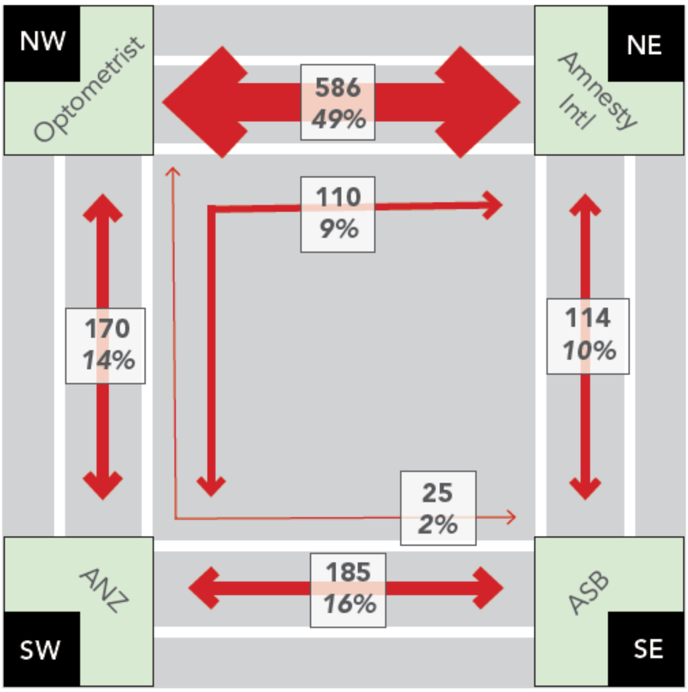


Figure 4: Pedestrian Crossing Movements at Victoria Street/Queen Street

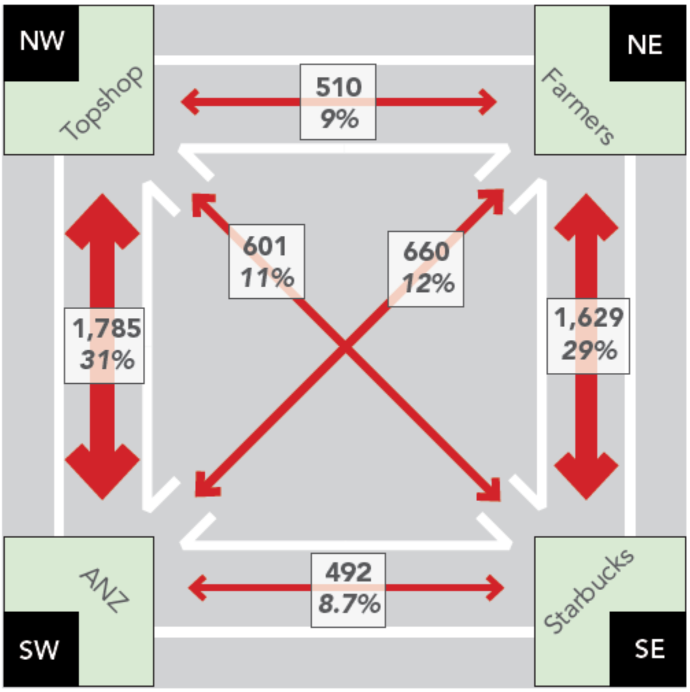
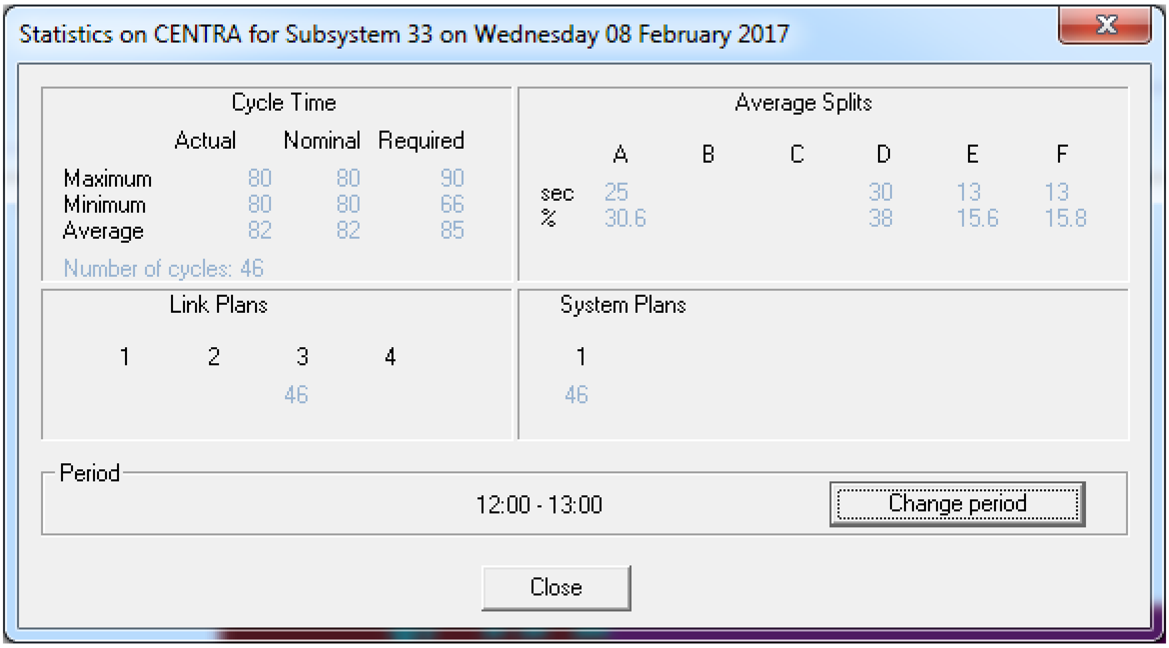


Figure 5 and Figure 6 display the midday signal phases at the two selected intersections. Based on this phasing, Table 3 estimates the average delay for pedestrians crossing in different directions across the intersection.

Figure 5: Summary of Signal Timing at Upper Queen Street / Karangahape Rd



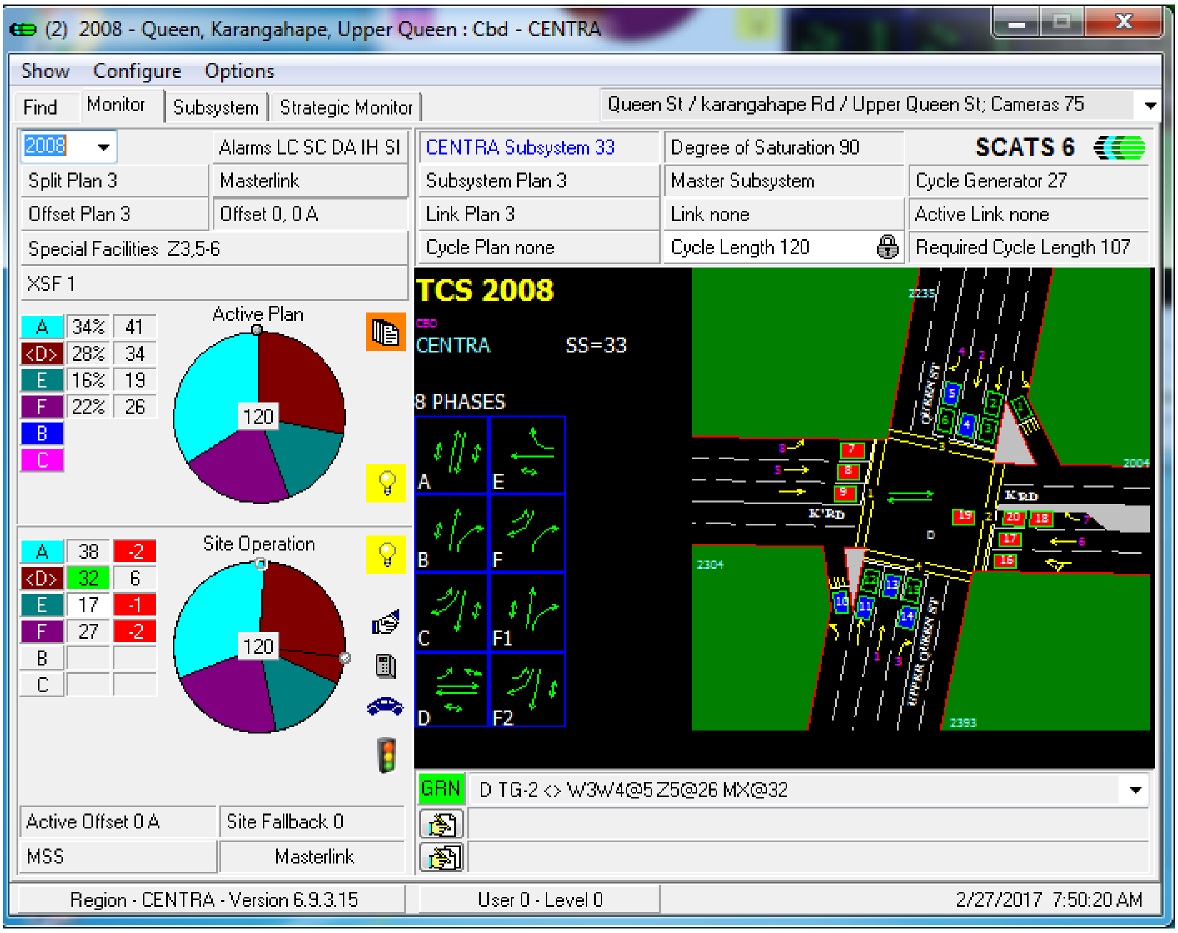


Figure 6: Summary of Signal Timing at Victoria and Queen Street

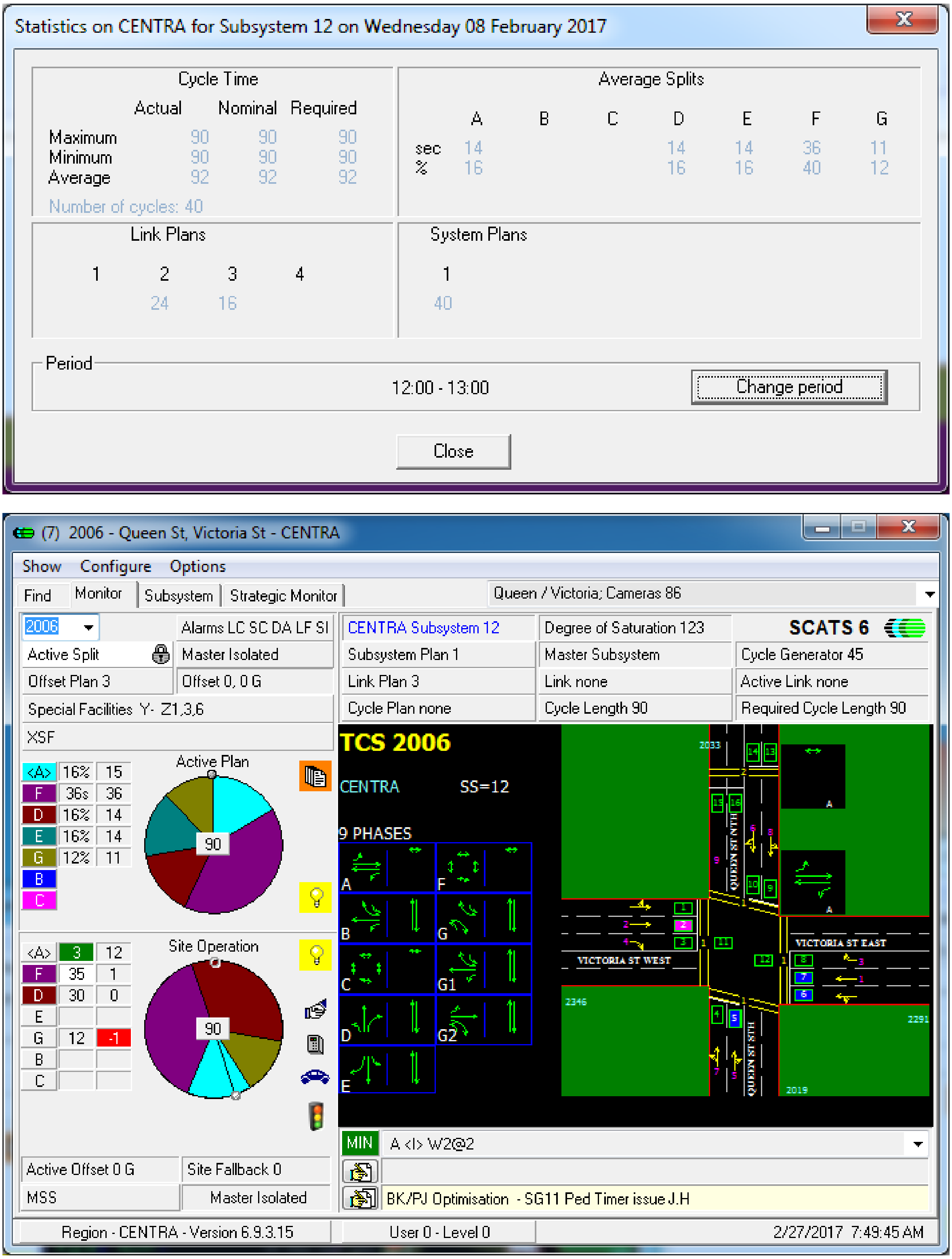


Table 3: Estimated average delay for pedestrians, by movement (consultants' estimate based on AT data)

Pedestrian movement	Queen St / Victoria St	Upper Queen St / Karangahape Rd
Intersection type	Barnes Dance	Two phase
Number of people who:		
Do not cross	0 sec	0 sec

Pedestrian movement	Queen St / Victoria St	Upper Queen St / Karangahape Rd
Cross one leg	26 sec	30 sec
Cross diagonally	29 sec	55 sec

The following charts summarise the data we have used to derive annualisation factors and show how pedestrian volumes vary between different times of day and different months. Figure 7 shows how pedestrian volumes vary between different times of day. Unlike traffic and public transport volumes, pedestrian volumes are highest in the middle of the day, and lower in the morning peak and evening. Similarly,

Figure 8 shows how average weekday pedestrian volumes vary throughout the year. This shows that pedestrian volumes are highest in spring and summer months, which have the best weather.

Figure 7: Average hourly pedestrian volumes for weekdays in February 2016

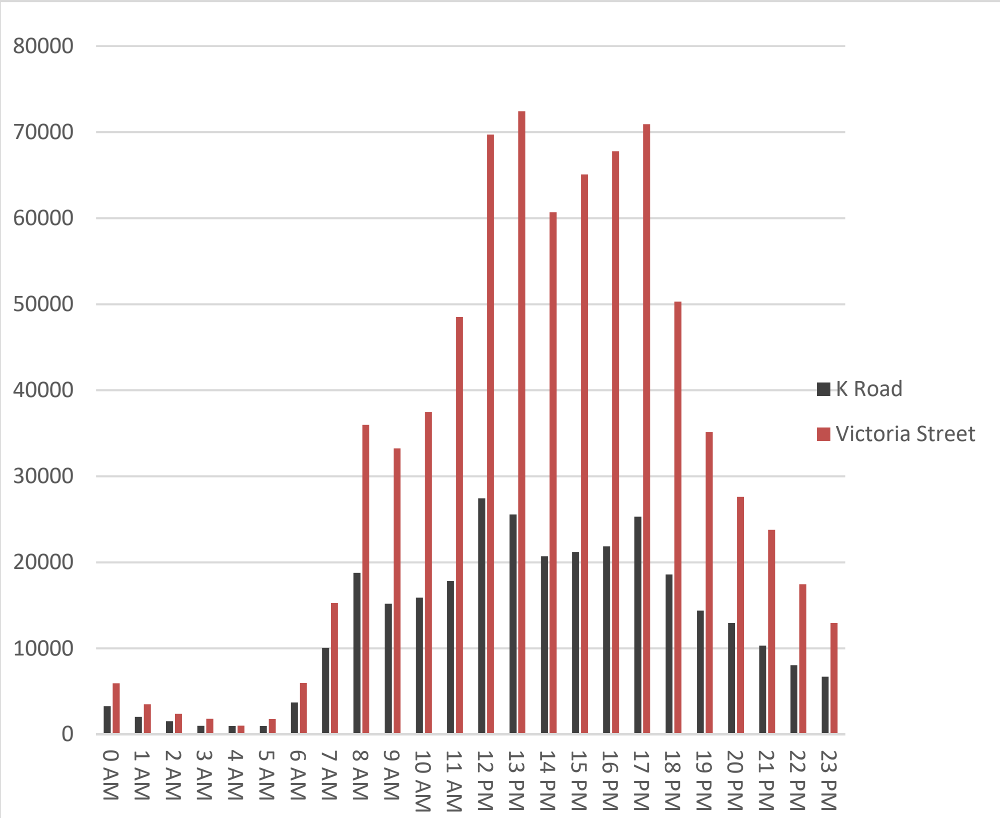


Figure 8: Average daily pedestrian volumes by month, 2016

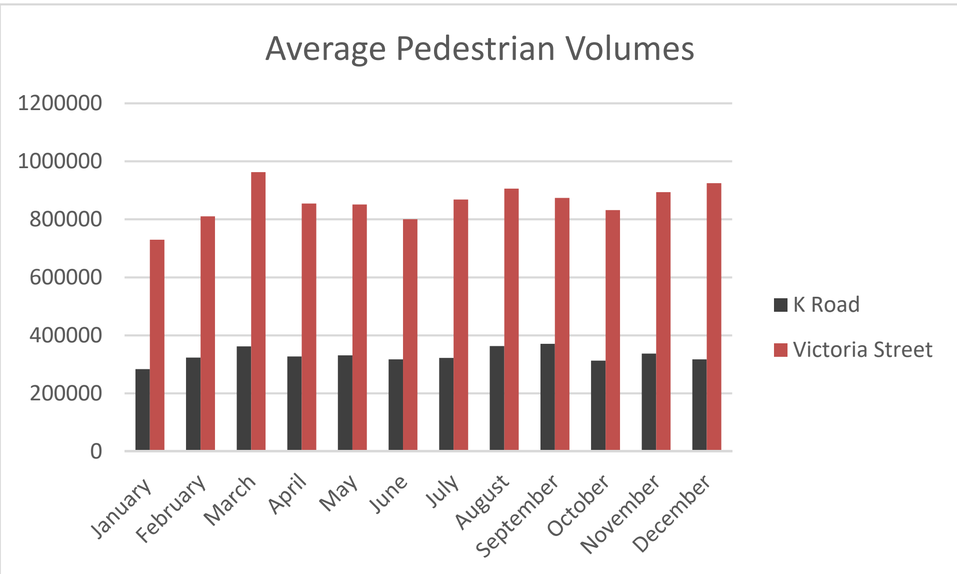


Table 4 summarises the resulting annualisation factors for the two intersections. We have estimated these based on data from 2016, rather than 2017, as data for the full 2017 year is not yet available. We based our annulisation factor on 9 February 2016 because it had comparable pedestrian counts, weather, and was also a weekday in early February.

Table 4: Annualisation factors used for two selected intersections (Heart of the City data)

Value	Queen St / Victoria St	Upper Queen St / Karangahape Rd
Location of counter(s) used	205 & 210 Queen Street	183 & 150 K Road
Pedestrian counts by time period		
Noon-1pm, 9 February 2016	3,518	1,397
All day, 9 February 2016	37,514	15,658
2016 calendar year	13,593,929	5,306,818
Ratios		
Ratio of peak hour to all-day	11	11
Ratio of all-day to annual	362	339
Annualisation factor	3864	3799

Finally, Table 5 summarises the estimated value of travel time for pedestrians travelling during this time period, based on relevant parameters from the NZ Transport Agency's (2016) *Economic Evaluation Manual*. As shown in the table, this estimate reflects variations in value of travel time between different trip purposes, with work-related travel assumed to have a higher value of time than other types of travel (including commuting journeys), as well as high-level assumptions about the composition of trip purposes.

Table 5: Estimation of value of travel time for pedestrians (NZ Transport Agency, 2016)

Variable	Value		
Trip purpose	Work-related trips	Commute trips	Other trips (eg shopping)
Share of travellers (Table A2.4; urban arterial road during daytime interpeak)	30%	10%	60%
Value of time in 2002 $/hr (Table A4.1(a), pedestrian and cyclist)	$21.70	$6.60	$4.25
Benefit update factor from 2002 to 2016 NZD (Table A12.3, travel time cost savings)	1.45		
Average value of travel time (2016 $/hr)	$14.10		

[Note: EEM general circulars 13-06 and 13-07 committed to equalising value of travel time across different modes. This change was not carried through to the 2016 version of the EEM for unknown reasons. Using the higher values of time assigned to car drivers results in a significantly higher figure of $17.50. For this report, the higher estimation has been used due to the intent to equalise the values. This figure can be found in Table 6]

Table 6: Estimation of value of travel time for all modes

Variable	Value		
Trip purpose	Work-related trips	Commute trips	Other trips (eg shopping)
Share of travellers (Table A2.4; urban arterial road during daytime interpeak)	30%	10%	60%
Value of time in 2002 $/hr (Table A4.1(a), pedestrian and cyclist)	$23.85	$7.80	$6.9
Benefit update factor from 2002 to 2016 NZD (Table A12.3, travel time cost savings)	1.45		
Average value of travel time (2016 $/hr)	$17.50		

This estimate of the average value of travel time for city centre pedestrians is likely to be conservative. According to Verhoef and Small (2007), value of travel time is related to income levels – people with higher incomes tend to place a higher monetary value on time savings. According to Statistics New Zealand data, median hourly earnings for employed people in Auckland were approximately 7-8% higher than median hourly earnings for New Zealand as a whole ($25.00 for Auckland; $23.22 for New Zealand as a whole).[5] This difference is likely to be even larger for the Auckland city centre, which has higher productivity levels than the city as a whole (Maré, 2008).

[5] See http://nzdotstat.stats.govt.nz/wbos/Index.aspx?DataSetCode=TABLECODE7472

3 Key results and discussion

This section presents the key findings from our analysis of the cost of pedestrian delay at two city centre intersections. It then places these results in context, including discussing the degree to which these results can be generalised to other city centre intersections. To conclude, we discuss potential implications of these findings for planning and management of the city centre transport network.

3.1 Summary of key results

Table 7 summarises key results of our analysis. During a typical midday peak hour in February, pedestrians experienced an aggregate total of 2,502 minutes of delay at the Queen St / Victoria St intersection and 633 minutes of delay at Upper Queen St / Karangahape Rd. The average delay per user is higher at the Upper Queen St / Karangahape Rd intersection, which reflects the fact that Barnes Dance intersections are comparatively efficient for pedestrians.

This translates into an estimated annual economic cost of $2.2M at the Queen St / Victoria St intersection and $714,000 at the Upper Queen St / Karangahape Rd intersection. This reflects a combination of lost productivity for work-related walking trips in the city centre and inconvenience for people making other types of trips. It has been calculated relative to free-flow conditions for pedestrians, which could be achieved by implementing a shared space treatment to allow pedestrians to move through intersections without delay.

For further context, we have extrapolated these results out over a future period and estimated the present value of these costs using the NZ Transport Agency's (2016) recommended 6% discount rate and 40-year evaluation period. This figure reflects the potential future value of a long-term improvement to pedestrian conditions at these locations.

Table 7: The cost of pedestrian delay for two selected intersections

Value	Queen St / Victoria St	Upper Queen St / Karangahape Rd
Number of pedestrians crossing intersection during selected time period (noon-1pm; 8 February 2017)	7,697	1,892
Pedestrian delay (minutes) during selected time period (noon-1pm; 8 February 2017)	2,502 minutes	633 minutes
Annual pedestrian delay (hours)	161,115 hours	40,106 hours
Average delay per pedestrian (seconds)	27 seconds	37 seconds
Annual economic cost of pedestrian delay ($)	$2.2M	$714,000
Discounted present value of future costs (40 year period; 6% discount rate)	$36M	$11.3M

The above outlined scenario imagines a free flow situation, where pedestrians would be able to cross at any point. This is likely unfeasible in many locations in the city centre, where many modes must converge. However, there are significantly fewer costs to pedestrians for optimised signal strategies, such as the double phase barnes dance signal strategy employed on Victoria and Queen Street prior to 2016. Table 8 outlines the cost of pedestrian delay under optimised signal strategies. For Victoria and Queen Street, the previous signal timing was used. For Karangahpe Road and Upper Queen Street, an equal pedestrian and car phase signal strategy was employed.

Table 8: Cost of pedestrian delay with optimised signal strategies

Value	Queen St / Victoria St	Upper Queen St / Karangahape Rd
Number of pedestrians crossing intersection during selected time period (noon-1pm; 8 February 2017)	7,697	1,892

Value	Queen St / Victoria St	Upper Queen St / Karangahape Rd
Pedestrian delay (minutes) for an optimised signal strategy	679 minutes	298 minutes
Annual pedestrian delay for optimised signal strategy (hours)	43,755 hours	18,888 hours
Average delay per pedestrian for optimised signal strategy(seconds)	20 seconds	20 seconds
Annual economic cost of pedestrian delay for optimised signal strategy ($)	$766,000	$336,000
Discounted present value of future costs for optimised signal strategy (40 year period; 6% discount rate)	$12M	$5.3M

When we compared the optimised signal strategy to the current signal strategies at these two intersections, it is apparent that noteworthy time savings are available with mild alterations to the signal timing without requiring a fully pedestrianised space. This is illustrated in Table 9. With only a difference of 7 seconds of delay, $1.5M of costs associated with pedestrian delay could be avoided on Victoria and Queen Street.

Table 9: Difference in costs of pedestrian delay between optimised and current signals

Value	Queen St / Victoria St	Upper Queen St / Karangahape Rd
Difference average delay	7 seconds	17 seconds
Difference in total delay	1,822 minutes	335 minutes
Difference in annualised Delay	117,360 hours	21,218 hours
Difference in annual economic cost of pedestrian delay	$1.5M	$370,000
Difference in discounted present value of future costs for optimised signal strategy (40 year period; 6% discount rate)	$24M	$6M

3.2 Placing these results in context

We have assessed the cost of pedestrian delay at two intersections out of a total of over 50 signalised intersections in the Auckland city centre, which we define as the area within the motorway cordon. Because many – but not all – city centre intersections have high pedestrian volumes, the aggregate cost of pedestrian delay in the city centre is likely to be large, and is potentially many times larger than our estimate for these intersections.

It is not straightforward to extrapolate these results to other intersections in the city centre, as the cost of pedestrian delay at intersections will vary depending upon pedestrian volumes, pedestrian movements across the intersection, and signal timing. Some limited extrapolation may be possible between intersections that are qualitatively similar, such as the four main Barnes Dance intersections on Queen St (at Quay St, Customs St, Victoria St, and Wellesley St). If we assume that these four intersections are broadly similar to the Queen St / Victoria St intersection we used as a case study, it would indicate that pedestrians experience around $11M in delay per annum at these four intersections, plus additional delay at T-intersections at Shortland St, Wyndham St, and Wakefield St.

However, the methodology developed in this paper could be extended to a broader area of the city centre if additional data or estimates of pedestrian flows was available. Automated pedestrian counter data, coupled with manual surveys, could be used to develop estimates of pedestrian flows around and across intersections, which could in turn be used to approximate the number of people crossing intersections in various directions.

To place these results in context, we compare them with published estimates of the cost of congestion for other road users. Wallis and Lupton (2013) estimate that in 2006, the total cost of congestion in Auckland (relative to free-flow traffic conditions) was around $1.25 billion. The cost of pedestrian delay at these two intersections alone is equivalent to around 0.3% of the region-wide cost of traffic congestion. We would expect the aggregate cost of pedestrian congestion in the Auckland city centre to equate to a significantly higher proportion of the overall cost of traffic congestion in Auckland.

3.3 Implications of these results

These findings suggest that changes to intersection timing and intersection design can result in large benefits or disbenefits for pedestrians in areas where there are a large number of people walking. This finding has implications for any proposed street design where pedestrians are present.

Although procedures in the NZ Transport Agency's *Economic Evaluation Manual* can be used to estimate benefits or disbenefits for pedestrians, these effects are not always (or even often) calculated when evaluating changes to the transport system. Accounting for the cost of delays for people in cars and buses but not for people on foot may bias the results of transport evaluations and result in policy recommendations that inadvertently reduce, not increase, transport network efficiency and economic productivity.

This bias is likely to be significant in areas where pedestrian volumes are high relative to vehicle volumes. As shown in Table 1, this is true for many city centre locations. Consequently, there is a strong case to ensure that pedestrian delays are accounted for when evaluating different options for managing city centre streets. We suggest that there are two key priorities for further research and evaluation.

First, it is important to ensure that evaluations of city centre focused transport projects, especially those with significant implications for intersection performance and walkability, take pedestrian delay into account. The methods developed in this paper can assist in delivering more holistic appraisal.

Second, it would be desirable to investigate opportunities to reduce pedestrian delay in the city centre. These may include a range of interventions, including but not limited to:

- Optimising intersection signal timing to optimise across all different movements, including pedestrians;
- Ensuring that the design of intersections accommodates both pedestrian and vehicle movements; and
- Decisions about how to allocate scarce road space between alternative uses, eg via shared street treatments that allow pedestrians more space to move freely along corridors or pedestrianised streets.

The figures discussed in this report do not account for increases in pedestrian volumes in the city centre. Given the anticipated capacity of planned public transport projects, the rapidly rising population of the city centre and greater region and the general trends of increasing pedestrian movements in the city centre, it would be safe to conclude that these figures are conservative when assessed on a longer-term basis. When considering long term strategic transport projects, projected pedestrian volumes should be used to accurately appraise the intersection's performance.