

# Measuring Pedestrian Delay

Quantifying the cost of pedestrian delay at signalised intersections in Melbourne's Central City

Final Report

**Prepared for:** Melbourne City Council

**Prepared by:** MRCagney Pty Ltd, Melbourne, Australia

## Document Information

<b>Project Name</b>	Measuring Pedestrian Delay in Melbourne's Central City
<b>Status</b>	Final Report
<b>Client</b>	Melbourne City Council
<b>MRC Reference</b>	AU 6526

MRCagney Pty Ltd  
Level 1, 134 Flinders Street  
Melbourne, VIC, 3000  
Australia

t: +61 3 8640 7970

e: [melbourne@mrcagney.com](mailto:melbourne@mrcagney.com)  
[www.mrcagney.com](http://www.mrcagney.com)

© 2018 MRCagney Pty Ltd ABN 11 093 336 504

This document and information contained herein is the intellectual property of MRCagney Pty Ltd and is solely for the use of MRCagney's contracted client. This document may not be used, copied or reproduced in whole or part for any purpose other than that for which it was supplied, without the written consent of MRCagney. MRCagney accepts no responsibility to any third party who may use or rely upon this document.

## Quality Assurance Register

Issue	Description	Prepared by	Reviewed by	Authorised by	Date
1	Draft Report	KB, DG, BT	PN	KB	28 June 2018
2	Final Report	KB, DG	KB, PK	KB	13 July 2018
3	Final Report, added Executive Summary	KB	KB	KB	9 August 2018

# Contents

<b>Executive Summary .....</b>	<b>5</b>
<b>1 Introduction .....</b>	<b>6</b>
1.1 Why measure pedestrian delay? .....	6
1.2 The study area .....	8
<b>2 Methodology .....</b>	<b>13</b>
2.1 Data .....	14
2.2 Model calculations.....	15
2.2.1 Calculating total pedestrian delays.....	15
2.2.2 Estimating annual pedestrian delays.....	17
2.2.3 Estimating value of pedestrian delays .....	18
<b>3 Results and discussion.....</b>	<b>19</b>
3.1 Summary of the results.....	19
3.2 Sensitivity testing results.....	23
3.3 Discussion and implications .....	25

## Figures

Figure 1: Crowding at the Spencer/ Collins Street intersection .....	7
Figure 2: Study area within Melbourne's central city .....	9
Figure 3: Intersections analysed in study .....	10
Figure 4: Comparing pedestrian and vehicle movements at Spencer Street intersections, 2017 .....	12
Figure 5: Pedestrian, tram and vehicle volumes by time of day, Spencer/ Collins Street intersection .....	12
Figure 6: Model workflow .....	13
Figure 7: Pedestrian movements at Spencer/ La Trobe Street intersection .....	16
Figure 8: Comparison of average pedestrian delay – current and proposed signal timings.....	21
Figure 9: Pedestrian delay across the day, current and proposed signal timings compared, aggregate for Spencer Street intersections with Little Bourke, Bourke, Little Collins and Collins Street .....	21
Figure 10: Estimated annual cost of pedestrian delays – current and proposed signal timings compared .....	22
Figure 11: Cost of pedestrian delay (compared with free-flow conditions), current signal timings.....	23
Figure 12: Summary of sensitivity test results - change in NPV of pedestrian delay from current to proposed signals, based on the low, base, and high range estimates for input assumptions.....	24

## Tables

Table 1: Existing average and proposed signal cycle times, Spencer Street intersections.....	11
Table 2: Scenario inputs .....	14
Table 3: Raw data inputs.....	15
Table 4: Summary of model assumptions.....	15
Table 5: Summary of pedestrian delay by intersection – current signal timings.....	20
Table 6: Summary of pedestrian delay by intersection – proposed signal timings .....	20
Table 7: Summary of pedestrian delay by intersection – difference between current and proposed signal timings .....	20
Table 8: Relative impact on cost of delays using the range of reasonable inputs .....	24

## Executive Summary

This report summarises the methodology and results of a study that improves understanding of the level of pedestrian delay currently being experienced at Melbourne's central city signalised intersections. The study is intended to inform decision-making on signal management within the central city and broader policy development for supporting a more walkable city.

The study uses transport economic evaluation methods to quantify the costs of current levels of pedestrian delay and potential benefits from reduced delay. The economic impacts of road traffic congestion and delay are routinely calculated to inform transport planning and cost-benefit analysis of transport projects. Equivalent analysis for people walking, however, is not commonly undertaken. Despite walking trips constituting 66% of internal transport trips within Melbourne's central city, pedestrian delay is currently an 'invisible cost' and is not generally considered in a systematic way when making decisions on allocation of space and time to different transport modes. Decision making on signal management within the central city is becoming increasingly important as walking activity grows and pedestrian crowding and safety problems at busy intersections becomes significant.

The study finds that average delays for pedestrians crossing Spencer Street are high, at between 40 – 51 seconds, reflecting long signal cycle times of approximately 120 seconds. These delays are high relative to measures in comparable central city locations in other cities and exceed the threshold of approximately 30 seconds delay where frustration for people walking increases markedly and signal compliance drops.

The City of Melbourne's proposed revisions to signal cycle times on Spencer Street would result in substantial reductions to pedestrian delay. Across the seven intersections on Spencer Street, pedestrian delay would reduce by more than 30%, with higher reductions at some intersections. For example, at the Spencer/Collins Street intersection average delay would reduce from 40 to 21 seconds during the AM peak period.

This study estimates economic benefits from these revisions to signal management, finding that across the four Spencer Street intersections where signal timing revisions are proposed, benefits are estimated to total \$6.3 million/ year or \$105 million in net present value terms over a 30-year evaluation period. This reflects reductions in travel time delay costs from approximately \$20 million/ year under current arrangements to \$13.7 million/ year. Benefits by intersection vary depending on pedestrian volumes and signal settings and range between \$0.6 million and \$2.7 million/ year. Economic costs involve lost productivity for work-related trips and loss of convenience for other types of trips.

This study provides a framework for analysis across a wider range of intersections and assessment of the impact of a broader programme of signal management reform within Melbourne's central city. The City of Melbourne has identified 45 of the 82 signalised intersections across the Hoddle Grid as immediate candidates for revised signal cycle times.

While this study has not compared economic benefits for people walking with potential increased delay for traffic from revising signal management, in central city contexts where pedestrian movements are much higher than vehicle movements (three times higher at the studied Spencer Street intersections), reducing pedestrian delay is likely to reduce aggregate person delay across transport modes. Shorter signal cycle times will also benefit tram users that are also significant users of central city streets.

Signal management may appear to be a somewhat trivial aspect of transport planning, but it is clear that effective signal management will not only increase connectivity across the city but can contribute to safer streets that work better for the city's multi-modal transport system, ensuring Melbourne's central city remains the thriving destination it is today.

# 1 Introduction

This report summarises the methodology and results of a study undertaken by MRCagney for the City of Melbourne that quantifies delay for pedestrians crossing signalised intersections on Spencer Street in Melbourne's central city. The purpose of the study is to improve understanding of the level of pedestrian delay currently being experienced at central city signalised intersections and to quantify potential benefits from reduced delay enabled by reduced signal cycle times.

The study uses transport economic evaluation methods to quantify the costs of current levels of delay and potential benefits from reduced delay. The economic costs of road traffic congestion and delay are routinely calculated to inform transport planning and cost-benefit analysis of transport projects. Equivalent analysis for people walking, however, is not commonly undertaken. Despite walking trips constituting the majority of transport trips within Melbourne's central city, pedestrian delay is currently an 'invisible cost' and is not generally considered in a systematic way when making decisions on allocation of space and time to different transport modes. This analysis allows for comparison of levels of pedestrian delay with delay to other users of the street.

The study is intended to provide a more rigorous evidence base to inform decision-making on revisions to signal cycle times at Spencer Street intersections, and more broadly, to inform the City of Melbourne's Transport Strategy Refresh and assist with decisions throughout the municipality on allocation of signal time between vehicles and people walking. The methodology established by this study provides a template that can be used as the basis for similar analysis at other intersections across the municipality.

This study focuses on understanding delay at signalised intersections for people walking and it does not attempt to undertake a comprehensive multi-modal analysis of signalised intersection management. Decision-making on reforms to signal management will also need to consider impacts on other street users including people in vehicles, trams, buses and freight movement.

This report is structured as follows:

- The remaining sub-sections of Part 1 provide context on the motivations for this study and the study area of Spencer Street
- Part 2 details the methodology used to measure and monetise pedestrian delay
- Part 3 discusses key results and implications for transport decision making in Melbourne's central city.

## 1.1 Why measure pedestrian delay?

Walking plays a significant role in Melbourne's central city transport system. In the City of Melbourne local government area, 66% of all internal trips are on foot (VISTA 2016), highlighting the importance of walking for short local trips and 'first-mile, last-mile' connections as part of longer distance public transport or motor vehicle trips. On an average weekday there are an estimated 324,000 walking trips within the municipality, far outnumbering the 61,000 private vehicle or 42,000 tram trips.<sup>1</sup>

The City of Melbourne recently published a background paper on walking as part of its Transport Strategy Refresh<sup>2</sup>, reporting that rapid future growth in central city walking activity will require substantial intervention in the allocation of limited road space and signal time to ensure a safe and attractive walking environment. Being at the centre of a growing metropolitan area, the central city is experiencing growing transport

---

<sup>1</sup> Victorian Government (2016) cited in MRCagney (2018) [City of Melbourne Transport Strategy Refresh, Walking – Background Paper](#).

<sup>2</sup> MRCagney (2018) [City of Melbourne Transport Strategy Refresh, Walking – Background Paper](#).

demands on its streets. Between 2004 and 2016 the average daily population within the City of Melbourne local government area increased from 680,000 to 900,000 and is projected to top 1.4 million by 2036.

The background paper highlighted an urgent need to respond to emerging problems with the walking environment in the central city and identified four key challenges:

- A. Crowding and delay
- B. Walking connectivity
- C. Inclusive spaces for life in the city
- D. Safety and security of the walking environment.

Current signal management practices were found to be a contributing factor to the crowding and delay problem. Relatively long signal cycle times at some intersections within the central city are contributing to both delay for people walking and significant crowding as streams of people walking congregate at intersections, waiting for lights to change. These problems are particularly acute at intersections around the central city's railway stations, including Spencer Street intersections around Southern Cross Station (see Figure 1). The Transport Strategy Refresh background paper's suggested responses to this challenge included recommendations to: 'review decision-making tools for re-allocating space and time among various street users' and 'optimise allocation of time at signalised intersections to maximise benefits for all users'. This study responds to both recommendations.

**Figure 1: Crowding at the Spencer/ Collins Street intersection**



The Walking Background Paper builds on earlier City of Melbourne work on understanding the benefits of improving walkability. The Walking Plan 2014-17<sup>3</sup> identified pedestrian crowding and delay as major problems

<sup>3</sup> City of Melbourne (2014) [Walking Plan 2014-17](#).



for walkability in the context of ongoing growth and included recommendations to investigate pedestrian delay at intersections and changes to signal operation at crowded intersections. The Plan was underpinned by an extensive evidence base, including work by SGS Economics and Planning on understanding the economic costs of poor walking connectivity (to which delay at signals can be a contributing factor). The SGS study estimated that a 10% reduction in walking connectivity within the Hoddle grid could result in economic costs of \$2.1 billion.<sup>4</sup> A review of signal operations by Traffinity also suggested assessing pedestrian delay times at signalised intersections and investigating opportunities to reduce signal cycle lengths.<sup>5</sup>

Since the City of Melbourne's 2014 work on walking, further international evidence has emerged which continues to highlight the economic consequences of walking conditions in central city environments. MRCagney undertook work in 2017 for Auckland Council on measuring the economic cost of delay to pedestrians at signalised intersections on Queen Street within Auckland's city centre. The study:

*"recorded pedestrian movements across two selected intersections on Queen Street, calculated the average length of pedestrian delay and quantified the economic cost of delay using New Zealand guidelines for economic evaluation of transport projects. It found that at a single intersection on Queen Street the value of pedestrian delay translates into an estimated annual economic cost of \$2.2 million, relative to free-flow conditions".<sup>6</sup>*

This study builds on the methodology developed by MRCagney in Auckland and applies it to intersections in Melbourne's central city. It both quantifies the level of delay being experienced by people walking in terms of time, and estimates an economic cost associated with this delay time.

Interest in walking delay reflects a growing international awareness of the importance of highly walkable environments for economic prosperity and quality of life, and the numerous benefits from health to spatial efficiency that come with shifting trips away from motorised transport to walking. While signalised crossing management can seem a trivial issue, it does have real impacts on people's transport decision-making. Professor of Transport, David Levinson has recently highlighted the significance of signalised intersection management:

*Planners tend to focus on the long-term decisions, like infrastructure and land development. However, it is the shortest of short-term decisions, how many seconds of green light each movement gets at an intersection, that shapes perception of the feasibility of walking or driving to a destination at a given time. This influences the choice of route, destination and mode of travel.*

*Traffic signal timing involves maths, so has been historically delegated to engineers. But it also involves values and priorities, and so is the proper subject of public policy.<sup>7</sup>*

In a Melbourne central city context, where walking should to be encouraged and where the walkability of the environment matters for the performance of the city, improved understanding of current walking conditions and the potential benefits from revised signal management is an important step for more informed future transport decision-making.

## 1.2 The study area

This study analyses pedestrian delay on Spencer Street (between La Trobe Street in the north and Flinders Street in the South), at the western edge of Melbourne's Hoddle Grid (Figure 2). Spencer Street is a heavily

---

<sup>4</sup> SGS Economics and Planning (2014) [Pedestrian Analysis Technical Report for the City of Melbourne](#).

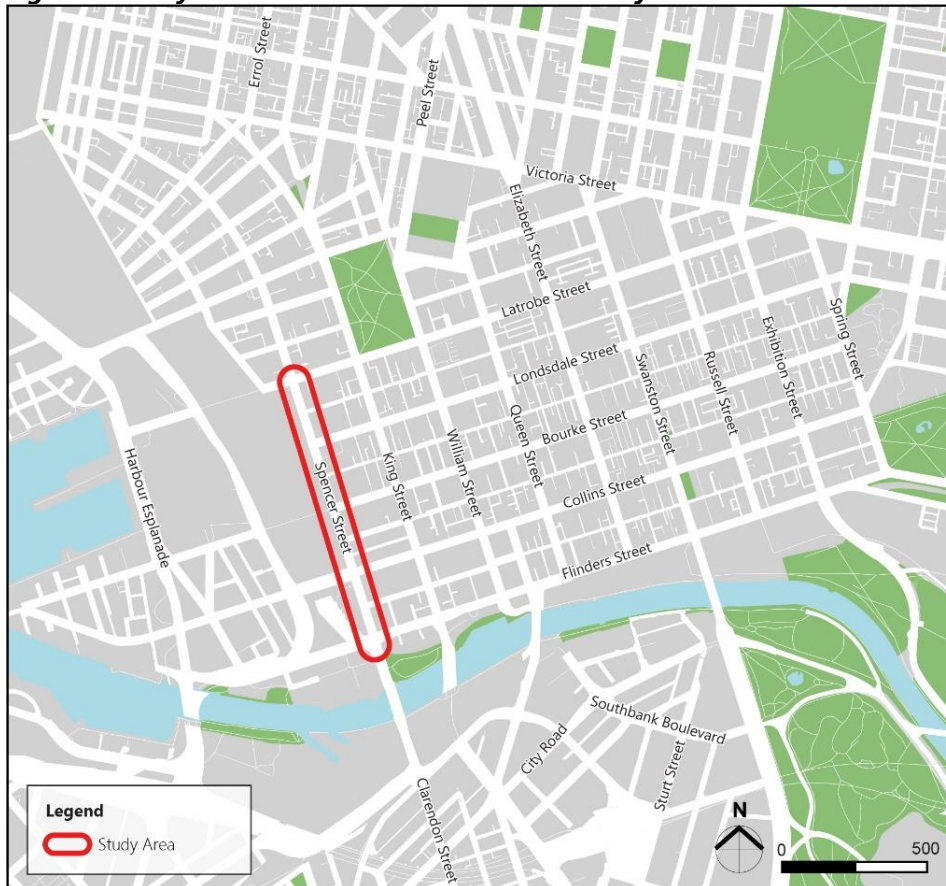
<sup>5</sup> Traffinity (2014) [Review of Signal Operations for Pedestrians in the City of Melbourne](#).

<sup>6</sup> MRCagney (2018) [City of Melbourne Transport Strategy Refresh, Walking – Background Paper](#).

<sup>7</sup> Levinson, David (2018) ['How traffic signals favour cars and discourage walking', The Conversation, June 11](#).

used central city street, with high levels of walking activity alongside road traffic and trams along its length south of La Trobe. Spencer Street forms a border between the Melbourne's historic commercial centre within the Hoddle Grid and the more recently developed Docklands area. Southern Cross Station sits adjacent to the street, between Bourke and Collins Street and is one of the city's major railway stations (see study area location in Figure 2).

**Figure 2: Study area within Melbourne's central city**

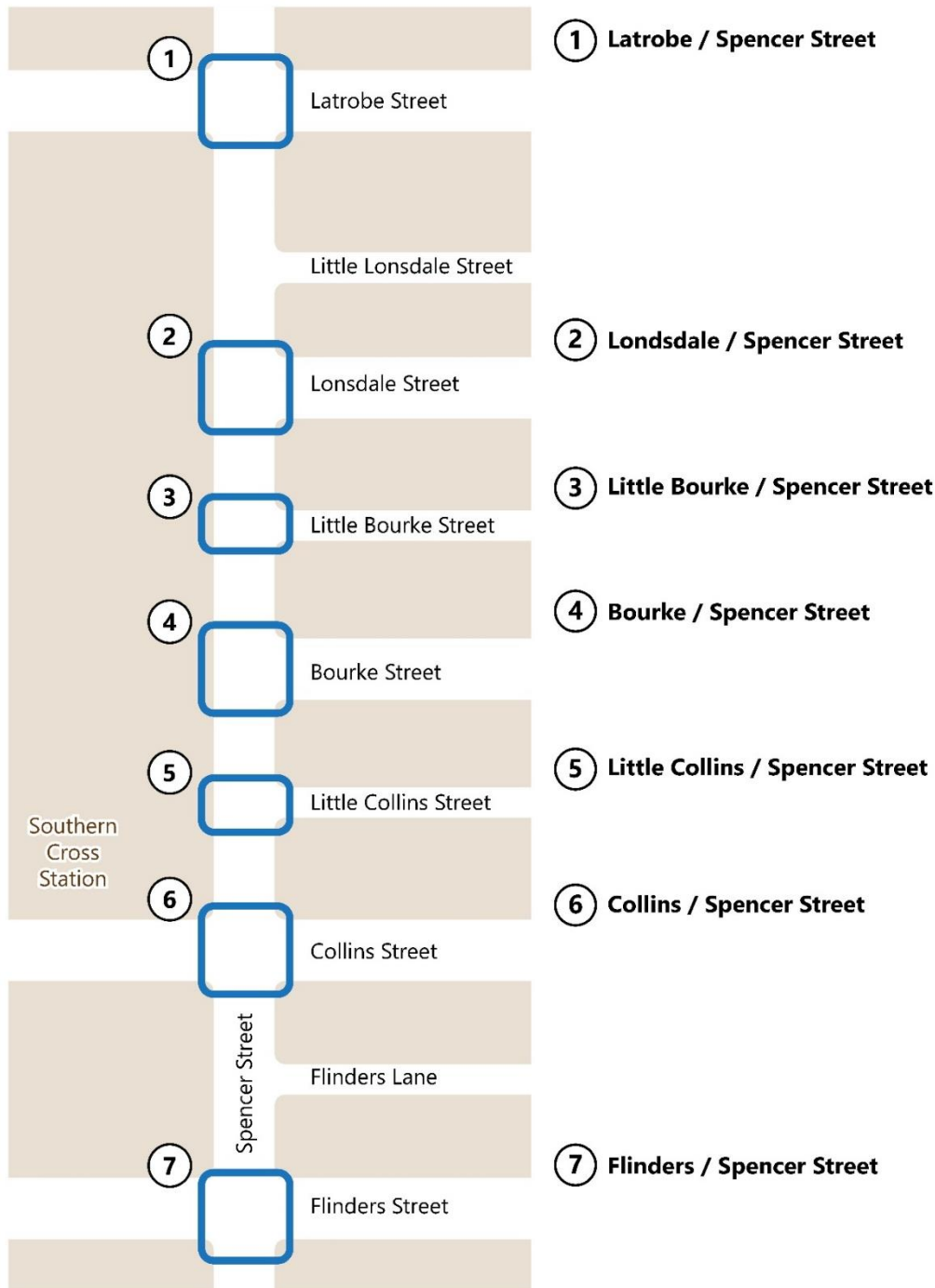


Spencer Street has been selected as a case study for testing the approach to measuring pedestrian delay for the following reasons:

- There are currently obvious instances of pedestrian crowding where people are waiting at signalised intersections for lights to change, particularly around access points to Southern Cross Station (eg intersection of Spencer and Collins Street).
- Current average signal cycles times at Spencer Street intersections are high (up to 120 seconds), relative to other central city intersections and international benchmarks for appropriate cycle times in central city environments. This creates an opportunity for reforms to signal management on Spencer Street.
- City of Melbourne, in partnership with VicRoads, are investigating improvements to the design of the street that ensure it better reflects the street's changing role as a multi-modal corridor rather than an arterial road prioritising traffic movement. This changing role reflects rapid development along the street and will be reinforced with planned reductions in traffic on Spencer Street accompanying the Western Distributor project.

- City of Melbourne envisage increased priority for walking, cycling and public transport on the broader Spencer Street corridor, including the continuation of Spencer Street to north of the Study Area.<sup>8</sup>

**Figure 3: Intersections analysed in study**



There are seven signalised intersection and two un-signalised intersections within the study area (see Figure 3). Intersections 2, 3, 4 and 5 are T-junctions with signals controlling three main pedestrian legs across the intersection. Intersections 1, 6, and 7 are cross roads with four primary pedestrian movements.

<sup>8</sup> City of Melbourne (2018) [West Melbourne Structure Plan](#).

Table 1 summarises existing and proposed average signal cycle times for the seven Spencer Street intersections. The signal cycle time is the total time taken to complete a full cycle of the various signal phases. While signal cycle times vary due to dynamic management of the signals in response to traffic conditions, the data below on existing times represent averages for different period of the day, based on VicRoads records from March 2018. The proposed cycle times have been proposed by City of Melbourne and involve reductions in cycle length for four of the seven intersections. This proposal aims to provide improved conditions and reduced wait times for people walking and in trams with a focus on reducing overall cycle times at intersections where pedestrian volumes are particularly high.

**Table 1: Existing average and proposed signal cycle times, Spencer Street intersections**

Intersection	Existing average cycle times (seconds)			Proposed average cycle times (seconds)			Level of change for AM period (existing/proposed)
	6am-11am	11am-1pm	1pm-8pm	6am-11am	11am-1pm	1pm-8pm	
<b>1. Latrobe</b>	120	110	110	120	110	120	No Change
<b>2. Lonsdale</b>	120	110	110	120	110	120	No Change
<b>3. Little Bourke</b>	120	110	110	60	60	60	-50%
<b>4. Bourke</b>	120	110	110	75	75	75	-62.5%
<b>5. Little Collins</b>	120	110	110	60	60	60	-50%
<b>6. Collins</b>	120	110	110	75	75	75	-62.5%
<b>7. Flinders</b>	120	117	123	120	110	120	No Change

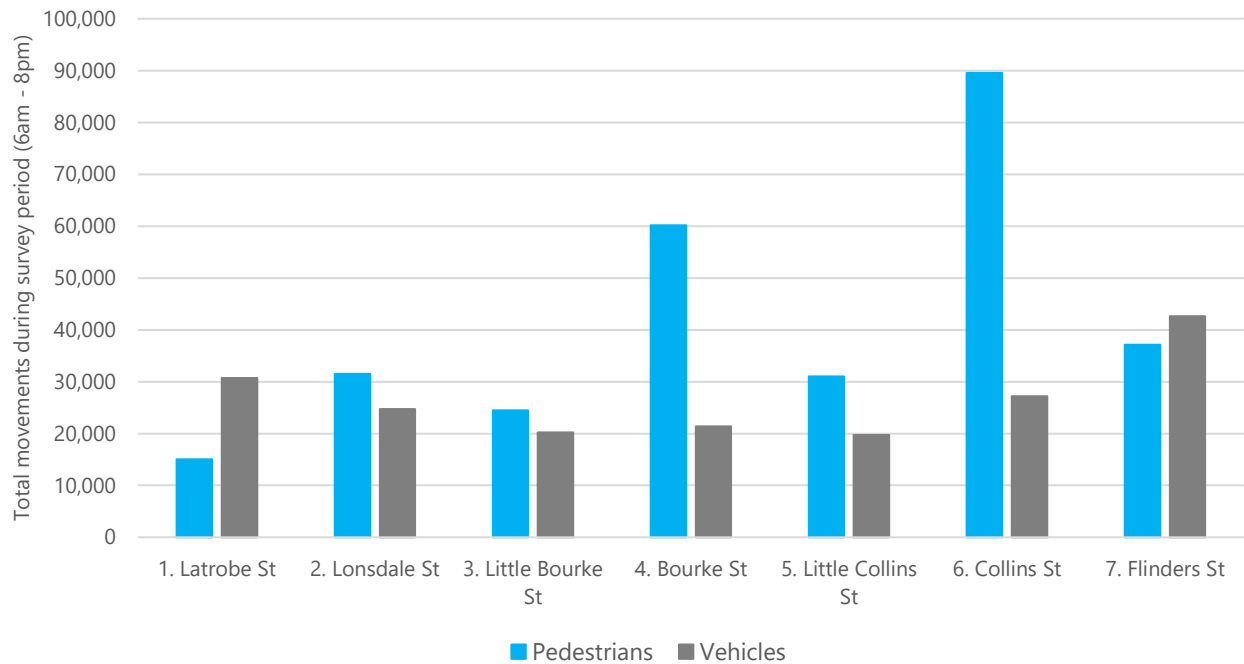
Source: Existing times - VicRoads (2018) Report of average cycle time from review of SCATS Traffic Reporter for Wednesday 21 March 2018, Proposed times - City of Melbourne (2018) Proposed AM-peak cycle times.

Figure 4 and Figure 5 illustrate current transport volumes at the signalised intersections within the study area. Figure 4 compares vehicle and pedestrian movements at each of the intersections, highlighting that the number of people walking at most intersections exceeds the number of vehicle movements. This is particularly the case at the Bourke Street and Collins Street intersections where pedestrian movements exceed vehicle movements by more than three times. Only at the La Trobe/ Spencer Street intersection do vehicle counts substantially exceed the number of people walking.

Figure 5 illustrates variation in pedestrian, tram and vehicle movements throughout the day at the Spencer/ Collins Street intersection, highlighting that pedestrian flows are highly variable and have sharp peaks in the morning and evening, coinciding with high levels of commuter activity at these times and people walking to and from rail services at Southern Cross Station. Tram flows have a similar trend to pedestrians, with peaks in the morning and afternoon peak commuting period. In contrast, vehicle flows are relatively constant throughout the day.

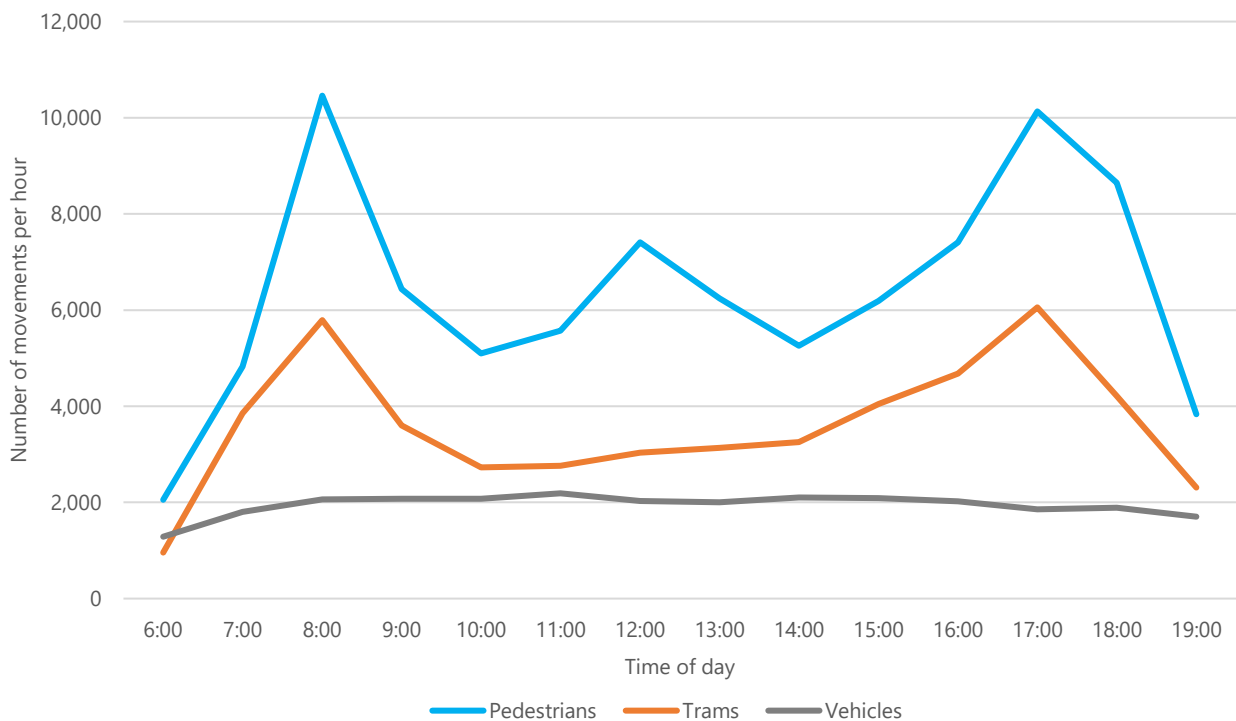
This information suggests that signal allocation between pedestrians and traffic that minimises total person delay across all modes will be particularly important at peak periods and at intersections such as at Bourke and Collins Street where pedestrian volumes are very high. Tram users will also benefit from improved signal management, as reduced cycle times (that provide more frequent pedestrian crossing opportunities) will also provide more frequent opportunities for trams to complete their movements. As the peak movements for trams and for pedestrians occur at similar times, the impact of reducing cycle times and phase lengths for vehicles at these times will reduce delays for most users of the intersection.

**Figure 4: Comparing pedestrian and vehicle movements at Spencer Street intersections, 2017**



Source: Thursday 9 March 2017, Thursday 16 March 2017, Thursday 12 October 2017 (all counts for each intersection were collected from single surveys).

**Figure 5: Pedestrian, tram and vehicle volumes by time of day, Spencer/ Collins Street intersection**



Source: City of Melbourne, AusTraffic Intersection and Pedestrian Count survey data from Tuesday 15 May 2018. Tram counts supplied by City of Melbourne.

## 2 Methodology

The approach to measuring pedestrian delay at the Spencer Street signalised intersections involves four main steps:

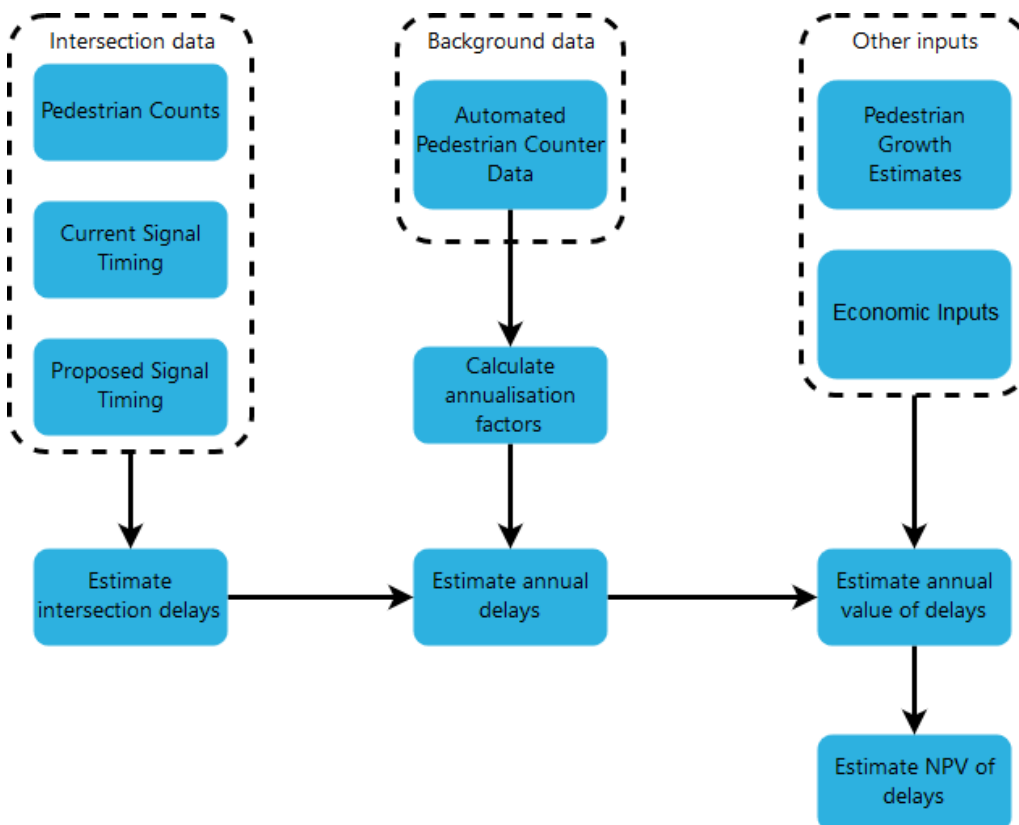
- Estimating pedestrian delays during a daytime survey period based on pedestrian counts and information on current and proposed signal timings
- 'Annualising' daily delay to establish an annual level of delay by comparing pedestrian counts for the survey day with data on pedestrian counts throughout the year
- Converting annual pedestrian delay into a monetised cost using transport economic evaluation inputs
- Converting annual costs into a net present value (NPV) over an extended evaluation period (30 years), consistent with common benefit cost analysis for transport economic evaluation.

These steps are shown in Figure 6. The following subsections provide more detail on the input data sources, assumptions and model calculations. The approach should be understood as 'modelling' rather than 'measuring' pedestrian delay, as it involves various assumptions to estimate the level and costs of delay.

Pedestrian delay is measured with respect to the following:

- Delay relative to 'free-flow' conditions (ie. if people walking could freely cross the street and not wait for any traffic)
- Reduction in delay from implementing the City of Melbourne's proposed revised signal cycle times at some of the Spencer Street intersections (see previous Table 7).

**Figure 6: Model workflow**



This methodology was peer reviewed by Peter Koonce, Division Manager, Signals and Street Lighting Division at City of Portland, Oregon, USA. Peter is an international expert on signal management and holds the Chair of the Transportation Research Board's Committee on Traffic Signal Systems.

## 2.1 Data

The model for estimating the value of pedestrian delays requires two types of inputs; data inputs and scenario/ assumption inputs. The scenario inputs are summarised in Table 2, whilst the data inputs are summarised in Table 3. Both 'central values' and a 'sensitivity range' are listed in Table 2. The central values are the recommended inputs and are the basis on which results are reported. However, it is important to understand how sensitive the model outputs are to these inputs. Section 3.2 of the results section reviews the impact on model outputs when each of the inputs are varied.

**Table 2: Scenario inputs**

Input	Central value	Sensitivity Range	Source for central value
Pedestrian growth rate (annual)	average 2.5% p.a.	75% - 125% of the forecast growth rate	City of Melbourne (2017) City of Melbourne Daily Population Estimates and Forecasts (and linear extrapolation beyond 2036 forecast).
Share of pedestrian trips for business purposes	15%	7 – 20% <sup>9</sup>	NZ Transport Agency (2016) Economic Evaluation Manual, Table A2.4; urban arterial road, average for all periods. <sup>10</sup>
Effective green phase extension (amount of time beyond end of green phase when pedestrians are assumed to continue to start crossing)	2 seconds	0 – 10 seconds	<b>2 – 8 seconds</b> recommended in the United States Department of Transportation Federal Highway Administration (1998) Highway Capacity Manual <sup>11</sup> , based on several observational studies, including in Queensland.
Value of travel time (non-business trips)	\$16.89 / hour	\$13.50 – 20.50	<b>\$14.99 (non-business), \$48.63 (business)</b> recommended in: Transport and Infrastructure Council (2016) Australian Transport Assessment and Planning (ATAP) Guidelines, PV2 Road Parameter Values, Table 12. <b>Inflation factor of 1.1269</b> applied, using Victoria's Wage Price Index to May 2017.
Value of travel time (business trips)	\$54.80 / hour	\$40 – 90 <sup>12</sup>	
Discount rate (for NPV)	7%	3 – 10%	Victorian State Government, Department of Treasury and Finance (2013) Economic Evaluation Guidelines.
Evaluation period	30 years	20 – 50 years	

<sup>9</sup> Precise information on the proportion of walking trips by purpose within Melbourne's central city is not available. Investigation of available data on trip purposes has been used to determine a range for sensitivity testing. The [Victorian Integrated Survey of Travel and Activity \(VISTA\) \(2013\)](#) reports that 26% of all trips for Metropolitan Melbourne residents are 'work-related', but within this categorisation does not distinguish between commuting and other business-related trips (eg trips to customers and suppliers). The [Transport for New South Wales Household Travel Survey](#) does distinguish business from commute trip purpose and finds that 7% of total trips within Metropolitan Sydney are for business purposes while 12% are for commuting. We use 7% as the low end of our sensitivity testing range. Applying the relative proportions of 'commute' and business-related' trips from Sydney to the 'work related' trips identified by VISTA data suggests approximately 9% of all trips across Metropolitan Melbourne are business-related (7%/(7%+12%)\*26%). While this provides an estimate for Metropolitan Melbourne, business-related trips are likely to be a higher proportion of total travel within the central city due to it being the densest concentration of business activity within Victoria. The Central Melbourne Travel Survey estimates that on week days 61% of Victorians are in the Central Melbourne Area for work-related purposes, while City of Melbourne daytime population estimates report that 42% of the daytime population across the city are workers. [Analysis of VISTA data](#) for the City of Melbourne local government area finds that within the municipality there are almost double the proportion of work-related trips than for the Melbourne Metropolitan average, (51% of total trips for City of Melbourne against 26% for Metropolitan Melbourne). Given this higher proportion of work-related trips, we can double the proportion calculated above for the metropolitan area to obtain an approximate estimate for the central city, suggesting business-related trips may be approximately 18% (2\*9% as calculated above).

<sup>10</sup> New Zealand transport economic evaluation guidance on this variable is used in the absence of Australian guidance on default values. The 15% value appears relevant for the Melbourne central city context given the review of data in note (7) above.

<sup>11</sup> United States Department of Transportation Federal Highway Administration (1998) Highway Capacity Manual; Chapter 13, "Pedestrians"; Recommended Procedures (1998) - Studies referenced observing effective green phase extensions of 2-7 seconds.

<sup>12</sup> Most workers in and around Melbourne produced over \$40/hour, with workers in the Melbourne CBD producing an average of \$87/hour (Grattan Institute (2014) [Mapping Australia's Economy](#), p. 18.)



**Table 3: Raw data inputs**

Input	Details	Source
Pedestrian counts	Survey data of pedestrian counts for each movement of each intersection. The inputs for the times, day and month of the survey are also required.	City of Melbourne, AusTraffic Intersection and Pedestrian Count survey data from May 2018.
Average signal cycle time	Average signal cycle time per intersection, at each time of the day.	VicRoads (2018) Report of average cycle time from review of SCATS Traffic Reporter for Wednesday 21 March 2018.
Pedestrian green phase time.	Pedestrian green light time for each movement at each intersection, for each time of day.	VicRoads (2012) Traffic Signal Configuration Data Sheets.
Automated pedestrian count data	One year of historical automated pedestrian counter data for Spencer St / Collins St.	City of Melbourne, Pedestrian Counting System data; February 2017 – February 2018.
Forecast pedestrian growth	Forecast daytime population estimates and forecasts for Melbourne CBD.	City of Melbourne (2017) City of Melbourne Daily Population Estimates and Forecasts.

## 2.2 Model calculations

Several necessary assumptions for the model calculations are described throughout this section. The various assumptions are summarised in Table 4, and referenced to the following sub-sections where they are more fully described.

**Table 4: Summary of model assumptions**

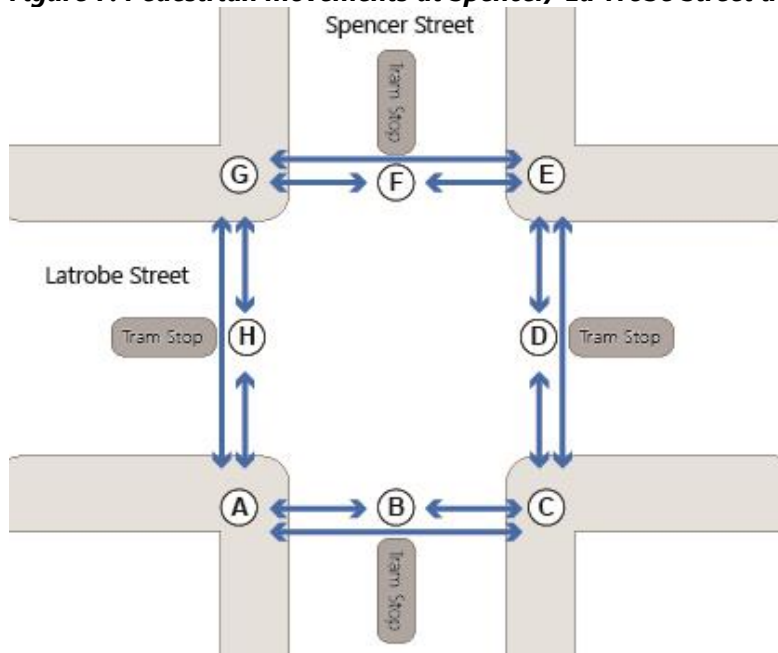
Reference	Assumption	Comments
Section 2.2.1	Pedestrians arrive randomly and uniformly (i.e. a similar number of pedestrians arrive in any small window of time).	This reflects the numerous factors which influence pedestrian arrival time, such as signal timing at other intersections, variations in walking speeds, etc.
Section 2.2.2	Average delay is approximately the same during the surveyed hours and the non-surveyed hours.	This impacts how the estimated delay during the survey period is factored up to a daily delay. It allows daily delay to be converted to annual delay based on the ratio of daily to annual pedestrian volumes.
	Surveyed pedestrian counts are typical for that day of the week and month of the year.	This impacts the annualisation factor.
Section 2.2.3	Daytime population (workers, residents, visitors) growth estimates, and linear extrapolations of these, will be reflected in future levels of pedestrian growth along Spencer Street.	The current predictions reflect a reasonably linear relationship between pedestrian volumes and daytime population, which is consistent with trends over the past decade.

### 2.2.1 Calculating total pedestrian delays

Pedestrian delays are calculated independently for every time period, for each movement at each intersection. The approach to calculating delay follows guidance from the United States Department of Transportation Federal Highway Administration (1998) Highway Capacity Manual. At each intersection there are several potential pedestrian movements (see Figure 7), all of which are counted by the pedestrian survey data.



**Figure 7: Pedestrian movements at Spencer/ La Trobe Street intersection**



When a pedestrian arrives at a signalised intersection, one of three events can occur:

- Case 1. The pedestrian signal is green, so the pedestrian can cross immediately.
- Case 2. The pedestrian signal has just started flashing red, and the pedestrian begins crossing anyway.
- Case 3. The pedestrian signal is flashing or solid red, so the pedestrian stops and waits.

The second case can be understood and modelled in the same way as the first case if we assume there is effectively an "extension" to the green phase time. We have included this as an option in the model, which can be changed, and have used a base value of 2 seconds (on which the results are reported) as the extension to green phase times. Pedestrians that experience either of the first two cases therefore experience no delay.

Pedestrians that arrive at an intersection with a red signal do, however, experience a delay. The average delay to these pedestrians can be modelled by understanding that for case three:

- 1. The maximum delay experienced will be the time of the red pedestrian phase (this is equal to the total cycle time minus the effective green phase time);
- 2. The minimum delay experienced will be 0 seconds (if they arrive just before the light turns green); and
- 3. Therefore, the average delay experienced will be half the red pedestrian phase time.

This can be expressed mathematically, assuming  $D^*$  = delay for case 3,  $C$  = total cycle time,  $G$  = effective green phase time, as follows:

$$D^* = \frac{C - G}{2}$$

The average delay for any given pedestrian must take into account the likelihood of a pedestrian arriving at the intersection in a green or a red phase. Assuming pedestrians arrive at the intersection randomly, the probability that they arrive during the red phase, is equal to the proportion of time the light signal is red.

Using the same variable definitions as above, and letting  $P$  = probability of arriving during red phase, this can be expressed as:

$$P = \frac{C - G}{C}$$

The expected delay to a random pedestrian is the probability that they arrive in the red phase multiplied by the average delay experienced by those pedestrians that arrive during the red phase. If we let  $D_{average}$  = the average delay experienced by any random pedestrian, this can be expressed as:

$$D_{average} = \frac{C - G}{C} * \frac{C - G}{2}$$

The average delay experienced by each individual pedestrian is then multiplied by the number of pedestrians that cross the intersection, using that signal (based on the pedestrian counts from the survey data). Therefore, the total delay experienced by all pedestrians for each movement, where  $D_{total}$  = total delay, and  $N_{pedestrians}$  = number of pedestrians, can be expressed as follows:

$$D_{total} = D_{average} * N_{pedestrians}$$

The conclusion of this step provides an estimate of total pedestrian delay for all movements of an intersection during the period (6am – 8pm) of the one-day pedestrian surveys used.

## 2.2.2 Estimating annual pedestrian delays

Average daily delay during the survey period needs to be factored up to calculate annual delay. The annual pedestrian numbers from the automated pedestrian counters at the Spencer St / Collins St intersection are used to understand the trends in pedestrian volumes throughout the day and the year. The survey data for this report was conducted from 6am – 8pm on a Thursday in April. The automated pedestrian counters observed that approximately 92% of pedestrians that are observed at intersections on Thursdays in April are present during those hours for this survey data. We were able to use this information to expand the calculated delays from the 14-hour survey period to the full 24-hour period. By directly factoring the total estimated delays from the 14-hour period to a 24-hour period, we assume that the average delay per person experienced in the 24-hour period is the same as the average delay experienced during the surveyed period. As signal timing is reasonably consistent throughout the day, this assumption appears to be reasonable.

The total estimated 24-hour delay can then be factored up to estimate the total annual pedestrian delays at each intersection. The annualisation factor assumes that the number pedestrians observed on the surveyed day represent the average number of pedestrians that would typically be observed on that day of the week and month of the year. The annualisation factor is calculated from the automatic pedestrian counters using the following equation:

$$\text{Annualisation factor} = \frac{\text{Annual pedestrians}}{\text{Typical pedestrians on survey day}}$$

The uplift factor used to uplift pedestrian delay from the 14-hour survey to a 24-hour day was 1.07, reflecting that pedestrian numbers at night, outside the survey period are relatively low. The uplift factor used to uplift 24-hour delay to annual delay was 305.7, suggesting that the daily pedestrian volumes on the survey day were slightly higher than the average across the year (to be expected, being a weekday and in May rather than, for example, during summer holidays).

### 2.2.3 Estimating value of pedestrian delays

Once the estimated pedestrian delays for the surveyed time period have been annualised, the economic value of those delays can be measured. Pedestrian trips are split into business (ie work-related travel) and non-business trips (eg commuting, shopping, leisure trips), each of which are assigned different travel time values. This follows Australian transport economic evaluation guidance. The average value of travel time per pedestrian is calculated based on the proportion and value of trips which are estimated to be for business and for non-business purposes. In the absence of precise information on the split between business and non-business trips for travel within Melbourne's central city, a central value of 15% business trips has been used (following NZ Transport Agency's economic evaluation guidance). Analysis of available data suggests this proportion is relevant for Melbourne's central city (see note 7).

The annual value of pedestrian delays is the total pedestrian delays multiplied by the average value of travel time for pedestrians. The annual value of pedestrian delays over time is impacted by the number of pedestrians using the intersections. Growth in the daytime population (an estimate of total residents, workers and visitors present in the municipality during an average day) is used to estimate the pedestrian growth at the Spencer Street intersections. These forecasts are only available until 2036, whilst the NPV timeframe goes beyond that period. The daytime population growth forecast has a reasonably linear trend, following the observed recent historical trend, so we have used a linear extrapolation method to predict pedestrian growth beyond 2036.

The annual cost of pedestrian delays, with considerations for growth in pedestrian numbers, is used to calculate the Net Present Value of pedestrian delays for each intersection, using a discount rate of 7% and evaluation period of 30 years, consistent with Victorian economic evaluation guidance.

## 3 Results and discussion

### 3.1 Summary of the results

Table 5 summarises the results of our modelling of pedestrian delay and associated monetised costs of this delay, under current signal timing arrangements and relative to 'free-flow' conditions where people could walk across intersections unencumbered.

We estimate that under current signal timing arrangements, for pedestrians that need to wait at a signal<sup>13</sup>, each person waits an average of between 40 – 51 seconds, depending on the intersection. Average delay per pedestrian is highest at the Spencer/ Flinders intersection (51 seconds) and lowest at Spencer/ Collins and Spencer/ Bourke (40 and 42 seconds respectively). This variation in average delay reflects different intersection arrangements and signal timings. The longer delays are explained by relatively short green time for pedestrian phases (7 or 8 seconds), while shorter delays generally reflect longer green time (12 – 16 seconds).

These figures reflect average delays. In reality, some people will experience shorter delays, or no delays, if they arrive at the right time. Other people will experience substantially longer delays, if they arrive just after the green period.

Across the seven signalised intersections within the Spencer Street study area, a total of 256,000 pedestrian movements were recorded during the survey period (6am – 8pm, Tuesday 15 May 2018), (see previous Figure 4). In the aggregate we estimate that on the survey day pedestrians experienced approximately 2,900 hours of delay time waiting at traffic signals, relative to free-flow conditions. Over a year, we estimate aggregate pedestrian delay to total approximately 887,000 hours.

Table 6 summarises assessment of delay relative to free-flow conditions under 'proposed' signal timing arrangements. The revised arrangements reflect guidance from City of Melbourne on viable potential changes to signal timing that provide shorter overall cycle times. Some signals are proposed to have substantial reductions to overall cycle time; for example, at Spencer/ Bourke, AM cycle times are proposed to be reduced from 120 seconds to 60 seconds.

Table 7 and Figure 8 summarises the difference in delay and monetised costs of delay between current and proposed signal timings. It shows that shortening overall cycle times can result in substantial reductions to pedestrian delay at signals. No reduction in delay is estimated for Spencer/ La Trobe or Spencer/ Lonsdale as the 'proposed' signal timing scenario includes no changes to timing for these intersections. Reductions are very minor for Spencer/ Flinders, reflecting very minor changes to overall signal cycle times.

Estimates of aggregate delay reflect a combination of average per person delay and pedestrian volumes at each intersection. Reductions in aggregate delay between the current and proposed signal cycle times total approximately 900 hours per day or 280,000 hours per year, a reduction of 32%. Reductions in aggregate delay are highest at intersections with high volumes of pedestrians, including:

- Spencer/ Collins: reduction in aggregate delay by 393 hours/ day or 120,000 hours/ year
- Spencer/ Bourke: reduction in aggregate delay by 274 hours/ day or 84,000 hours/ year.

<sup>13</sup> Some pedestrians recorded by the pedestrian counts used for the analysis do not have to wait at a signal due to the movement either being unsignalized or not involving a road crossing – ie. pedestrian movement on the side of a T-junction without a crossing. These pedestrian movements are excluded for calculating average wait time.

**Table 5: Summary of pedestrian delay by intersection – current signal timings**

Intersection	Average delay per pedestrian that has to wait (seconds)	Estimated total delays on survey day (hours)	Estimated total annual delay (hours)	Estimated annual cost of delays (\$ millions)	Estimated NPV (\$millions)
1. Spencer / La Trobe Street	47.0	180	54,978	\$ 1.24	\$ 20.61
2. Spencer / Lonsdale Street	46.6	403	123,119	\$ 2.78	\$ 46.16
3. Spencer / Little Bourke Street	46.0	156	47,729	\$ 1.08	\$ 17.90
4. Spencer / Bourke Street	41.8	618	188,857	\$ 4.26	\$ 70.81
5. Spencer / Little Collins Street	44.4	261	79,825	\$ 1.80	\$ 29.93
6. Spencer / Collins Street	39.7	843	257,766	\$ 5.82	\$ 96.65
7. Spencer / Flinders Street	51.4	440	134,557	\$ 3.04	\$ 50.45
<b>Total</b>		<b>2,901</b>	<b>886,831</b>	<b>\$ 20.02</b>	<b>\$ 332.51</b>

**Table 6: Summary of pedestrian delay by intersection – proposed signal timings**

Intersection	Average delay per pedestrian that has to wait (seconds)	Estimated total delays on survey day (hours)	Estimated total annual delay (hours)	Estimated annual cost of delays (\$ millions)	Estimated NPV (\$millions)
1. Spencer / La Trobe Street	47.0	180	54,978	\$ 1.24	\$ 20.61
2. Spencer / Lonsdale Street	46.6	403	123,119	\$ 2.78	\$ 46.16
3. Spencer / Little Bourke Street	10.1	68	20,803	\$ 0.47	\$ 7.80
4. Spencer / Bourke Street	23.3	344	105,181	\$ 2.37	\$ 39.44
5. Spencer / Little Collins Street	12.5	109	33,416	\$ 0.75	\$ 12.53
6. Spencer / Collins Street	21.2	450	137,518	\$ 3.11	\$ 51.56
7. Spencer / Flinders Street	50.2	430	131,608	\$ 2.97	\$ 49.35
<b>Total</b>		<b>1,984</b>	<b>606,622</b>	<b>\$ 13.70</b>	<b>\$ 227.45</b>

**Table 7: Summary of pedestrian delay by intersection – difference between current and proposed signal timings**

Intersection	Average change in delay per pedestrian (seconds)	Change in total delays on survey day (hours)	Change in total annual delay (hours)	Change in annual cost of delays (\$ millions)	Change in NPV of delay cost (\$millions)
1. Spencer / La Trobe Street					
2. Spencer / Lonsdale Street					
3. Spencer / Little Bourke Street	- 35.9	- 88	- 26,927	-\$ 0.61	-\$ 10.10
4. Spencer / Bourke Street	- 18.5	- 274	- 83,676	-\$ 1.89	-\$ 31.37
5. Spencer / Little Collins Street	- 31.9	- 152	- 46,409	-\$ 1.05	-\$ 17.40
6. Spencer / Collins Street	- 18.5	- 393	- 120,248	-\$ 2.72	-\$ 45.09
7. Spencer / Flinders Street	- 1.1	- 10	- 2,949	-\$ 0.07	-\$ 1.11
<b>Total</b>		<b>- 917</b>	<b>- 280,209</b>	<b>-\$ 6.33</b>	<b>-\$ 105.06</b>

**Figure 8: Comparison of average pedestrian delay – current and proposed signal timings**

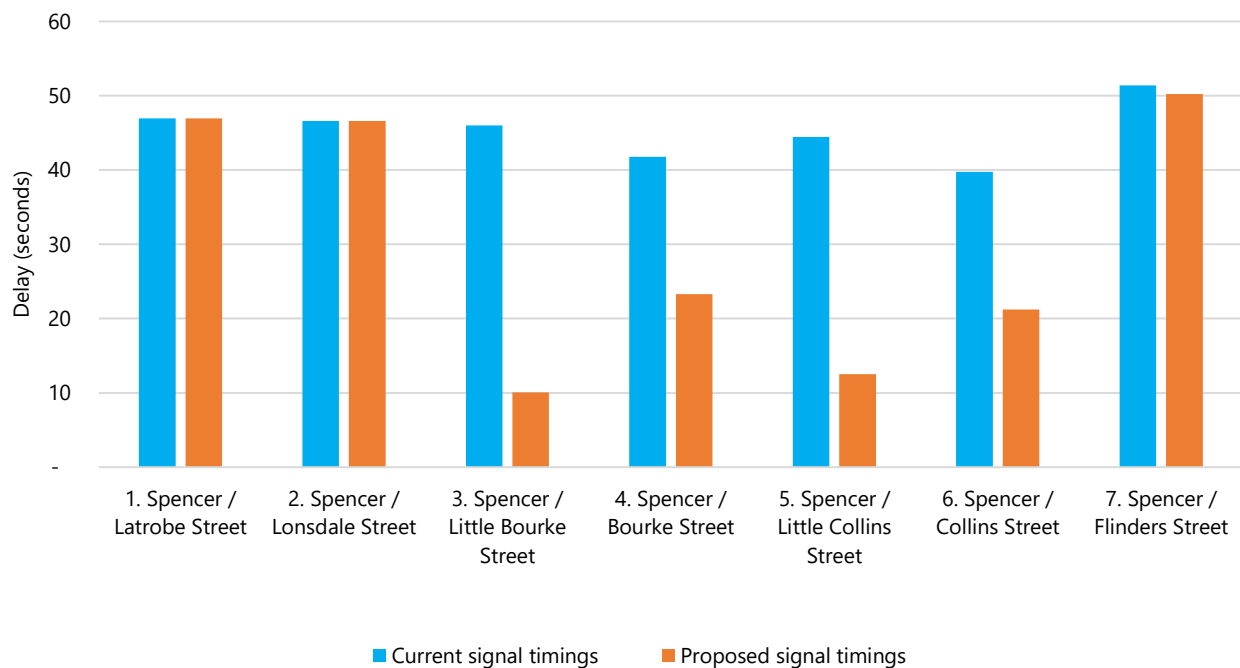
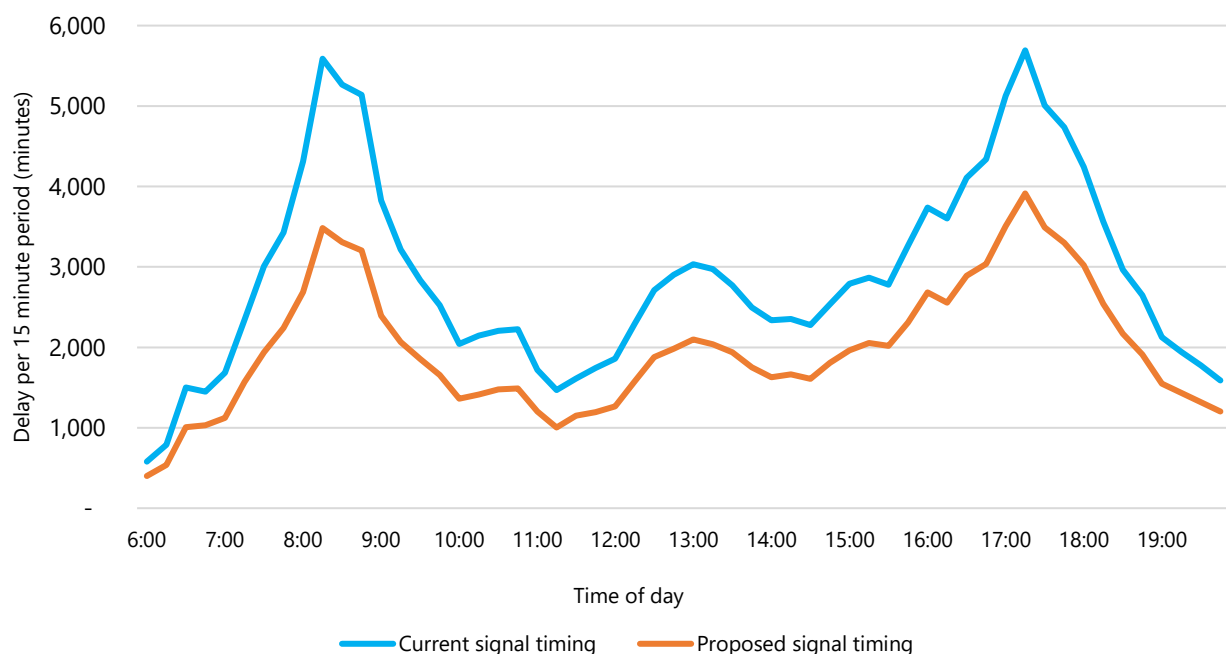


Figure 9 illustrates how aggregate delay is distributed across the day. The proposed signal timing arrangement results in reduced delay across the entire day, with the most substantial reductions at peak periods. This reflects high volumes of pedestrians at these periods benefiting from shorter wait times. At some intersections, aggregate pedestrian delay during the AM peak could be reduced by approximately 50% with the implementation of the proposed signal time revisions (eg at Spencer/ Collins).

**Figure 9: Pedestrian delay across the day, current and proposed signal timings compared, aggregate for Spencer Street intersections with Little Bourke, Bourke, Little Collins and Collins Street**

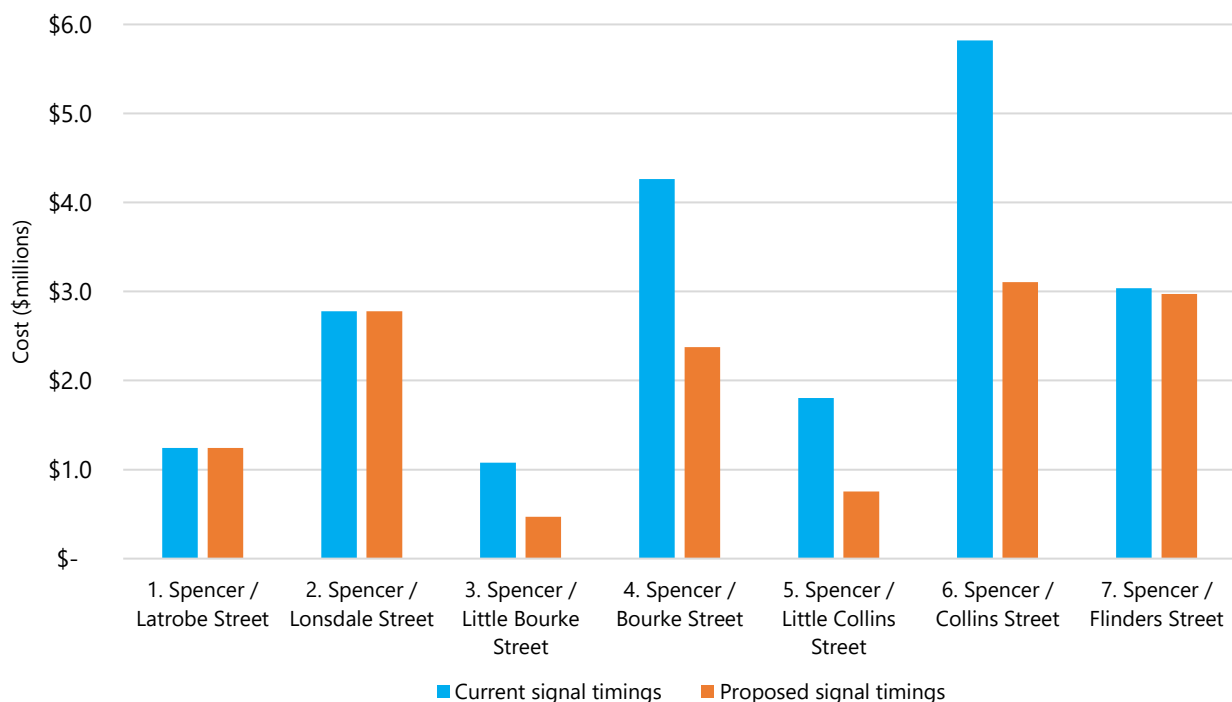


The study has also 'monetised' the economic cost of pedestrian delay following conventional transport economic evaluation practices. In the aggregate, we estimate that under current signal arrangements the 'cost' of pedestrian delay relative to free-flow conditions is approximately \$20.0 million/ year across the seven Spencer Street signalised intersections. This is an estimate of the 'opportunity cost' of the time that people must spend waiting at intersections, relative to alternative things that they could be doing with their time. For business trips, this has a direct economic cost, as it represents time that could otherwise be applied to productive purposes. For other trips, it may simply reflect increased frustration or a loss of time for recreational use.

Free flow conditions for pedestrians are unlikely to be obtainable at the intersections due to the presence of trams and traffic and comparison between the current and proposed signal timing arrangements provides a more meaningful sense of the potential level of cost savings (or economic benefits) from reduced pedestrian delay. Under the revised signal timing scenario, annual costs of delay are estimated to reduce to \$13.7 million, representing travel time savings benefits of \$6.3 million/ year.

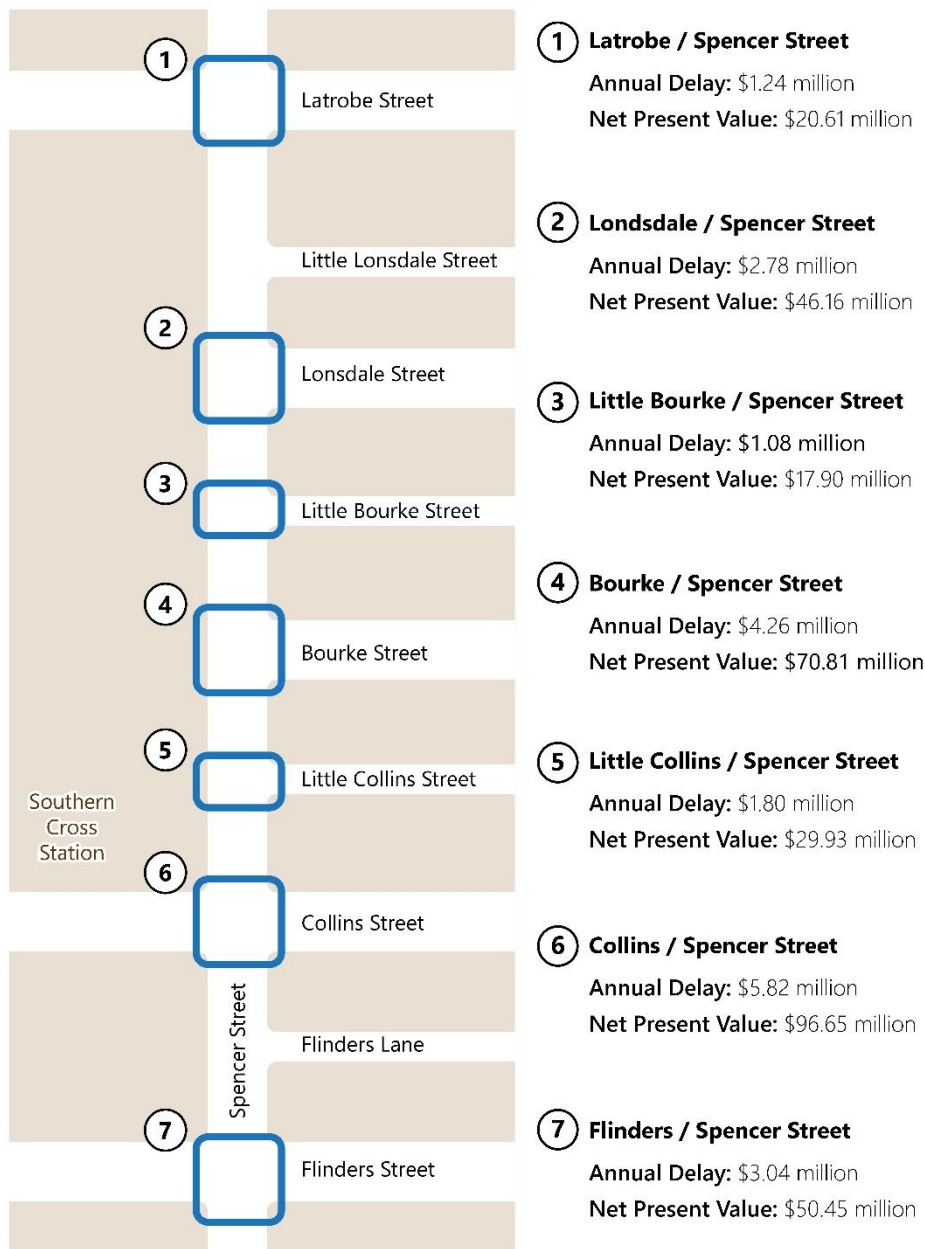
Figure 10 illustrates how economic costs are reduced across the seven intersections. This clearly depicts the difference between the current and proposed signal timings; the cost of delay at the Bourke Street and Collins Street intersections would be reduced by around 45% by adopting the proposed signal timings. The Latrobe Street and Lonsdale Street intersections have no proposed changes to signal timings and the Flinders Street intersection has minimal changes.

**Figure 10: Estimated annual cost of pedestrian delays – current and proposed signal timings compared**



For placing these results in the context of economic benefits from travel time savings evaluated for other transport projects, we also estimate a Net Present Value (NPV) arising from reduced pedestrian delay. Over a 30-year period, accounting for future growth in pedestrian numbers in Melbourne's city centre and discounting the value of benefits in future years, we estimate the NPV of travel time savings benefits to be \$105 million across the seven intersections. Figure 11 shows the estimated cost of pedestrian delay (compared with free flow conditions) at each intersection under current signal timings.

**Figure 11: Cost of pedestrian delay (compared with free-flow conditions), current signal timings**



## 3.2 Sensitivity testing results

Model outputs can be sensitive to the inputs, meaning that the model results vary significantly, even with potentially small changes to input assumptions. It is important to understand the extent of this sensitivity, particularly if there are a range of reasonable input assumptions. For example, one of the input assumptions for the model used for this study, is the “effective green phase extension” (how long people are likely to continue crossing once the pedestrian signal starts flashing red). Some studies have indicated that a reasonable value for this is 2-7 seconds, however, this variable would depend on a number of factors, including vehicle volumes, and pedestrian and vehicle behaviour at any given intersection. As such, we have identified a reasonable range for this variable to be 0-10 seconds (0 seconds representing full pedestrian compliance with the signals and 10 seconds representing frequent crossing on red-flashing signals).



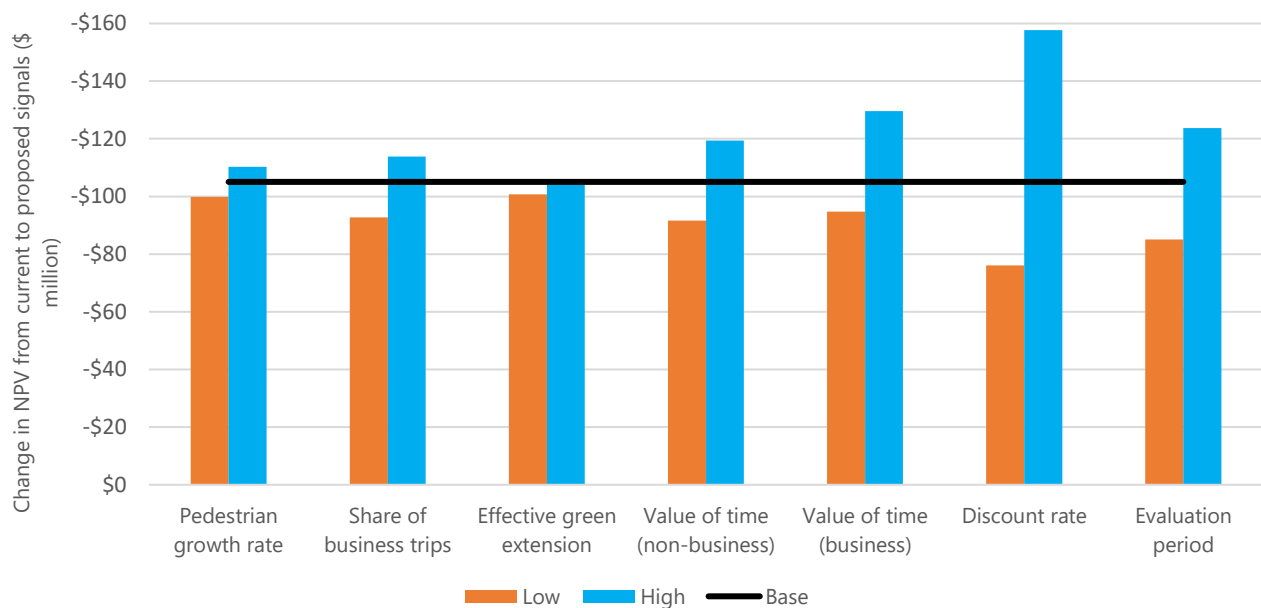
Table 8 summarises the lowest and highest relative change to the estimated annual cost and NPV of delays for the range of reasonable inputs for each scenario assumption. Each sensitivity test uses the central values, as outlined in Table 2, with the only variable changed being the one being tested. Figure 12 summarises the results of this sensitivity testing in chart form and reports on the difference in NPV of pedestrian delay between the current and proposed signal timings.

**Table 8: Relative impact on cost of delays using the range of reasonable inputs**

Variable	Value range tested	Impacts	Low	Base	High
Pedestrian growth rate	75 - 125% of forecast	Only NPV	0.95	1	1.05
Share of business trips	7 - 20% of trips	Annual cost and NPV	0.88	1	1.08
Effective green extension	0 - 10 seconds	Annual cost and NPV	0.96	1	1.01
Value of time (non-business)	\$13.50 - 20.50 /hour	Annual cost and NPV	0.87	1	1.14
Value of time (business)	\$40 - 90 /hour	Annual cost and NPV	0.90	1	1.23
Discount rate	3 - 10% <sup>14</sup>	Only NPV	0.72	1	1.50
Evaluation period	20 - 50 years	Only NPV	0.81	1	1.18

The variable with the largest impact on the NPV of delays is the discount rate; a discount rate of 10% reduces the base case NPV savings of delays from signal changes by 28% (\$29 million) whilst a discount rate of 3% increases the base case NPV savings from signal changes by 50% (\$53 million). The evaluation period used to calculate the NPV also has a reasonably large impact on results, with longer evaluation period increasing the NPV of delay costs.

**Figure 12: Summary of sensitivity test results - change in NPV of pedestrian delay from current to proposed signals, based on the low, base, and high range estimates for input assumptions**



The value of time assumptions have the next highest impact on estimated delay costs, with the low end for the value of non-business travel resulting in a decrease in annual savings of delays of 13% (\$0.8 million) from the proposed signal changes, and the high estimate for the value of business travel increasing the estimated annual savings by 23% (\$1.5 million). The results are less sensitive to the pedestrian growth and effective green time assumptions.

<sup>14</sup> A discount rate of 3 seconds generates the higher NPV of delays, whilst higher discount rates reduce the NPV of delays.

### 3.3 Discussion and implications

This study has found average pedestrian delays at Spencer Street signalised intersections within Melbourne's central city are high, and that in the aggregate, pedestrian delay imposes an economic cost. With regard to average per person delay, the results suggest that average delays of 40 – 51 seconds at the Spencer Street intersections is high relative to delay measured in comparable locations in other cities and benchmark desirable maximum wait times at signalised crossings in city centre environments.

The average delay times are higher than average delays of 27 – 37 seconds recorded by a similar recent study of Auckland city centre intersections.<sup>15</sup> Vallyon et al review the international literature on pedestrian's perceptions of acceptable wait times at signalised crossings and find that beyond a threshold of about 30 seconds, frustration for people walking increases markedly.<sup>16</sup> This has translated into transport planning guidance in Germany recommending against overall signal cycle times of more than 90 seconds. The high average pedestrian delays on the Spencer Street intersections are largely a consequence of relatively long cycle times, typically of approximately 120 seconds.

The study's comparison of pedestrian delay time under current signal timing arrangements and a proposed scenario of reduced signal cycle times (as proposed by City of Melbourne) confirms that this change to signal operations will result in substantial reductions to pedestrian delay. These reductions have not been compared with potential increases to delay for traffic, but in the Spencer Street context where pedestrian movements are up to three times higher than traffic movements, reducing pedestrian delay while increasing traffic delay may well result in lower aggregate person delay. Shorter signal cycle times will also benefit tram users that constitute a substantial proportion of total passenger movement along Spencer Street (tram passengers significantly outnumber vehicle movements, although are lower than pedestrian volumes). As trams have dedicated corridor space they are generally at the head of any queue waiting for signals and so are able to benefit from shorter cycle times. People cycling can experience similar benefits.

In a policy context where walking, cycling and public transport use is being encouraged, reductions to delay for these modes can assist in shifting their attractiveness relative to using cars. Regardless of policy settings, pedestrian volumes in Melbourne's central city are projected to increase substantially in future and this is likely to only increase the case to revise timing of signalised intersections.

Within the Spencer Street study area, changes to signal management that increase allocation of time to pedestrians are likely to bring particularly substantial benefits in the following contexts:

- Intersections with very high volumes of pedestrians – eg Spencer/ Collins and Spencer/Bourke
- Signal timing at morning and evening peak periods, when pedestrian volumes are very high.

With regards to the level of aggregate pedestrian delay and monetised economic cost of this delay, this study finds that the travel time costs of people waiting at signals at the seven intersections assessed ranges from \$1.1 - \$5.8 million/ year. This reflects costs of lost productivity for work-related trips and loss of convenience for other types of trips. This compares with an equivalent study in Auckland that assessed two city centre intersections and estimated delay costs of NZ\$0.7 million and NZ\$2.2 million/ year. The higher delay costs at some of the Spencer Street intersections can be explained by:

- Higher pedestrian volumes at some intersections
- Higher levels of average per person delay at all intersections

<sup>15</sup> MRCagney (2017) Measuring Pedestrian Delay, prepared for Auckland Design Office, Auckland Council.

<sup>16</sup> Vallyon, C., Turner, S., & Hodgson, S. (2011). *Reducing pedestrian delay at traffic signals* (No. 440). NZ Transport Agency.

- A higher value of travel time used, consistent with Australian rather than New Zealand transport project economic evaluation guidance.

Alongside calculating total pedestrian delay relative to 'free-flow' conditions, this study has also estimated the economic benefits of revising signal cycles. It estimates economic benefits from reducing signal cycle times at between \$0.6 - \$2.7 million/ year per intersection. This compares with benefits associated with 'optimised signals' in the Auckland study of between \$0.4 - \$1.5 million/ year for each of the assessed intersections. Across the four Spencer Street intersections where signal timing revisions are proposed, economic benefits of reduced delay costs are estimated to total \$6.3 million/ year or \$105 million in NPV terms over a 30-year evaluation period.

Presenting these economic benefits in NPV terms allows for the results to be placed in context of other transport project evaluations. For example, recent economic evaluation of the Westgate Tunnel, a major Victorian transport project, found the NPV of travel time savings to be \$1.6 billion.<sup>17</sup> Evaluation of the Melbourne Metro Program found the NPV of public transport user benefits (which includes travel time savings alongside a range of other benefits) to be \$4.7 billion.<sup>18</sup> While the \$105 million of benefits for reducing pedestrian delay at four Spencer Street intersections is obviously far lower than that from these major projects, extrapolating the results of this study across the many signalised intersections within Melbourne's central city with very high levels of walking activity suggests that aggregate travel time savings from enhanced signal management across the central city will not be insignificant in the context of broader metropolitan transport planning.

There are 82 signalised intersections within the Hoddle Grid area of the central city and many more across the municipality. The City of Melbourne has identified 45 of the 82 Hoddle grid intersections as immediate candidates for reduced signal cycle times.<sup>19</sup> While there certainly is scope for significant benefits from signal management changes across the Hoddle Grid, we do note that the level of walking travel time savings benefits estimated for Spencer Street intersections may not be representative of the potential for benefits at other intersections, meaning that simple extrapolation of benefits across other intersections is not straight forward. Signal cycle times are higher on Spencer Street (as they also are on King Street), than across the rest of the Hoddle Grid (between 60 and 90 seconds) meaning that the level of pedestrian delay occurring at Spencer Street intersections with very high pedestrian volumes is likely to reflect the high-end of the range of pedestrian delay being experienced at single intersections across the central city.

Further analysis of pedestrian volumes and delays at other locations within the central city will help understand the full extent of the potential benefits of revised signal management practices across the municipality. This study has established an assessment framework that can be readily applied to evaluation of other intersections. Fuller economic evaluation of signal revisions would also need to consider a more comprehensive range of costs and benefits including offsetting costs from increased traffic delay, additional travel time benefits to public transport users and road safety benefits.

Only four of the seven intersections assessed on Spencer Street were treated with significant reductions to signal timings as part of the proposed change scenario. We recommend further investigation into reducing signal cycle times at the other intersections of Spencer/ Flinders, Spencer/ Lonsdale and Spencer/ La Trobe. Current cycle times of 120 seconds at these intersections are long for central city contexts relative to international practice (and even relative to the rest of Melbourne's central city), and we recommend that a maximum of 90 second cycle times is likely to be appropriate for all intersections across Melbourne's Hoddle Grid. Currently within the Hoddle Grid only King Street and Spencer Street intersections have average signal cycle times of more than 90 seconds. Shorter cycle times will support multi-modal movement rather than

<sup>17</sup> PricewaterhouseCoopers Australia (2015) Western Distributor Economic Assessment Report for the Victorian Department of Treasury and Finance, p. 92.

<sup>18</sup> State Government of Victoria, Metro Tunnel (2017) Melbourne Metro Business Case – Appendix 6 Economic Evaluation, p. 43.

<sup>19</sup> Information supplied by City of Melbourne, document dated 2012. It is unclear to what extent these previously proposed revisions have been implemented to date.

simply prioritising vehicle flow, appropriate to central city contexts vehicle movement is only one element of a more complex multi-modal transport system.

This study has clearly established that people walking in Melbourne's central city experience significant delay waiting at signalised intersections. There is an economic cost to delay and proposed changes to signal management can substantially reduce this cost at the studied intersections. While signal management is frequently delegated to technical experts and may seem trivial, choices about how to manage signals have important implications. Effective signal management will not only reduce walking delay and increase connectivity across the city, but can contribute to safer streets that work better for the city's multi-modal transport system, ensuring Melbourne's central city remains the thriving destination it is today.