Guideline

Options for reducing pedestrian delays at traffic signals

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Queensland Government

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1 Introduction

This guideline provides the supporting documentation, background context and research for the additional treatments presented in Technical Note TN191 *Reducing pedestrian delays*.

1.1 Purpose and scope

The purpose of this guideline is to identify options to help reduce pedestrian delays at traffic signals. This guideline outlines existing treatments identified in Austroads guidance and introduces additional treatments for consideration, being setting an optimal maximum cycle time focused on pedestrian level of service and pedestrian green wave.

This guideline identifies physical, technological, social and environmental barriers to implementing treatments and elements to consider, for setting an optimal maximum cycle time for pedestrians and pedestrian green wave. This guideline will help practitioners consider the suitability of treatments to support an appropriate pedestrian environment at traffic signals and to prioritise pedestrian movements.

This guideline focuses on potential traffic signal operational treatments that reduce pedestrian delay. Implementing quality infrastructure is important to provide a safe, appropriate road environment and helps reduce crossing times for pedestrians. Documents covering infrastructure changes applicable to intersections include:

- the Transport and Main Roads' supplement to Austroads' *Guide to Traffic Management*, Volume 1 of the *Traffic and Road Use Management (TRUM) manual*
- Transport and Main Roads' supplement to Austroads' *Guide to Road Design*, Volume 3 of the *Road Planning and Design Manual* (RPDM)
- Transport and Main Roads' Standard Drawings
- Transport and Main Roads' Transport and Main Roads' *Queensland Manual of Uniform Traffic Control Devices* (MUTCD), and
- Austroads' *Guide to Road Design* (AGRD) and *Guide to Traffic Management* (AGTM).

Section 1.3 provides further detail on the information these documents provide.

1.2 Background

High pedestrian use areas

Central business districts (CBD) and key activity centres generate high levels of pedestrian activity via movement along paths; access to adjoining land uses such as office complexes, retail, cafes and food stores and recreation at key meeting locations. Roads serve two primary roles for users: facilitating movement or acting as places for people. Road corridors in areas of high pedestrian activity, such as CBDs and activity centres, are beginning to focus more on the pedestrian scale and 'place' function, as opposed to the traditional focus of traffic 'movement' and throughput function.

Movement and Place Framework

Austroads' *Guide to Traffic Management Part 4* outlines the Movement and Place Framework to manage priorities between movement and place. Locations with high levels of pedestrian use and activity focus more towards the place axis of the framework. This includes city centres, activity centres, transport hubs and interchanges and major community uses such as universities and hospitals.

Transport for NSW research identified qualities that road users value most for their travel mode. For pedestrians, the most valued qualities included connectivity and flow, as well as safety and security. With CBDs and activity centres becoming more 'pedestrianised', these movements should be recognised and appropriately catered for to support safe and effective connections and movement.

Purpose of traffic signals

Traffic signals are usually implemented to assist with safety or operational issues at existing intersections, such as to reduce crashes, conflicts or vehicle delays, or provide an improved level of safety and mobility to new intersections.

Austroads' *Guide to Traffic Management Part 10* states that, while traffic signals have improved the safety and performance of intersections, they are not generally accepted as a Safe System treatment as they are typically not forgiving when user error results in a crash. Traffic signals do, however, contribute to a safer road, safer users and safer use as they provide time separation between different road user movements and they tend to change the focus of users from gap acceptance (finding a gap in traffic to allow the user to continue) to compliance with signals (obeying the green and red phases). Reducing pedestrian delay is likely to improve compliance and overall safety.

Austroads' *Guide to Traffic Management Part 13* identifies that traffic signals and the management of signals can contribute to road user needs by improving:

- mobility – adjusting signal timings to reduce delay for priority road users; improve signal coordination along a corridor; address network-wide congestion; discourage vehicle movements where required to support other modes and support freight and public transport movements
- safety – prevent conflicts between users; restrict unsafe movements and provide protection to vulnerable road users, and
- access – improve level of service and equity for side road access.

Austroads' *Guide to Traffic Management Part 13* further states that traffic signals can provide additional support to control and manage access to the network and dissipate traffic to assist with incident management.

In relation to the Movement and Place Framework, traffic signals tend to focus on the movement aspect of the framework and result in priority given to vehicles. In high-use pedestrian areas, this priority to vehicles can adversely affect pedestrian travel times, the quality of the physical environment and delay the efficient and safe movement of pedestrians.

1.3 Relationship to other documents

The following documents provide general guidance on the importance of pedestrian level of service, the coordination of traffic signals and general information regarding pedestrian priority; however, current guidance and analysis on the effects and appropriateness of treatments and solutions for reducing pedestrian delays at traffic signals, is limited.

Details of other publications referenced in this guideline are provided in the *Active transport users guidelines references* publication.

1.3.1 Austroads

Guide to Road Design

The Austroads *Guide to Road Design Part 4* (GRD Part 4) provides general information on pedestrian preferences for signalised intersections, particularly for those with restricted mobility, as signalised intersections provide a greater guarantee of right-of-way. The GRD Part 4 further suggests signalised intersections with significant pedestrian volumes should restrict left-turning traffic to passing through the signals, rather than turning.

The Austroads *Guide to Road Design Part 6A* (GRD Part 6A) provides guidance that locations with high and consistent pedestrian volumes, such as inner-city areas, should prioritise pedestrians and where practicable, coordinate traffic signals to improve pedestrian levels of service. The GRD Part 6A further suggests that, walking environments for pedestrians, should be as continuous as practical and allow for streets to be crossed easily and safely with minimised delays.

Guide to Traffic Management

The Austroads *Guide to Traffic Management* (GTM) has several Parts relevant to pedestrians, traffic signals and delays. Table 1.3.1(a) provides a summary of the relevant information contained within the GTM.

Table 1.3.1(a) – Summary of Guide to Traffic Management

Part	Application to pedestrian delays at traffic signals
Part 4: Network Management Strategies	• Identifies the Movement and Place Framework that identifies the types of environment focused on movement and on places (Section 2). • Identifies that pedestrians should be prioritised in areas of high or very high place significance such as activity centres (Section 2.1). • Identifies traffic signal timings as a general hazard encountered by pedestrians (Section 3.7.3).
Part 6: Intersections, Interchanges and Crossings Management	• Identifies the potential treatments for addressing excessive delay for pedestrians at signalised crossings, pedestrian crossings, refuge islands, median, kerb extensions and grade separation (Section 2.4.1). • Identifies maximised signal coordination for priority users, but notes it may require longer cycle times, leading to longer delays to adjacent road users (sections 4.1 and 4.2).

Part	Application to pedestrian delays at traffic signals
Part 7: Activity Centre Transport Management	• Identifies that, within city centres, the emphasis should be on pedestrian movement, rather than vehicle movement (Section 2.3.2). • The primary focus for planning and design for walking in activity centres, is on the quality of the walking environment such as safety, convenience and connectivity (Section 2.3.2). • Identifies intersection performance targets for pedestrian wait time should be as low as possible, along with vehicle throughput and traffic density (Section 3.8.2). • Identifies pedestrian throughput as a design parameter in high activity areas (Section 3.8.2).
Part 9: Transport Control – Types of Devices	• Identifies treatments and signal timings that can be implemented to provide priority to pedestrians at traffic signals (Section 6.3.2) (additional information provided in Section 3.1 of this guideline). • Identifies various signal timings and settings to ensure safety and minimise delay (Section 6.7.12). • Identifies pedestrian detection and consideration for fixed demand for pedestrian movements in high-use pedestrian areas (Section 6.8.9). • Supported by Austroads' *Signal Management Techniques to Support Network Operations*.
Part 12: Integrated Transport Assessments for Development	• Identifies excessive pedestrian delays can lead to higher levels of non-compliance at traffic signals and encourages pedestrian delays to be kept low (Section 4.4.10). • Encourages road safety audits to check pedestrians do not experience excessive delays such as a long traffic signal cycle time (Section 4.4.10).

***Guide to Road Safety* and Safe System approach**

The Austroads *Guide to Road Safety* provides guidance on creating safe transport infrastructure, road environments and safety for all users. While the *Guide to Road Safety* is not directly related to reducing pedestrian delays, it does provide guidance on developing pedestrian crossing management plans to maintain safety and reduce risks (refer to *Guide to Road Safety Part 4*).

The Safe System approach captures the guiding principles that underpin the *Guide to Road Safety*. The Safe System approach recognises crashes are likely to occur and the transport environment should be designed, managed and maintained to reduce the risk and consequences if a user makes a mistake. The Safe System approach focuses on four pillars that underpin the planning and design of transport corridors and their surrounding environments. These pillars involve providing safe roads, speeds, vehicles and road use.

For additional information on the Safe System approach, refer to Austroads' *Guide to Road Safety Part 1* and *Guide to Road Design Part 1*.

Table 1.3.1(b) describes how the Safe System pillars can be applied to traffic signals and reduce pedestrian delays to create a safe travel environment.

Table 1.3.1(b) – Safe Systems pillars applied to pedestrian delays at traffic signals

Pillar	Application to pedestrian delays at traffic signals
Safe roads	• Less opportunity for conflicts between motorised vehicles and pedestrians. • Reduces the unpredictability of pedestrians crossing in front of oncoming traffic when they are required to give way to vehicles.
Safe speeds	• Provides enough time for pedestrians to travel through the intersection. • Removes travel time delays for pedestrians when stopping, to allow other users to cross through the intersection.
Safe vehicles	• Vehicles using the intersection less likely to cause significant harm if conflicts occur with pedestrians. • Greater compliance by pedestrians to traffic signal phasing.
Safe road use	An intersection environment designed to support safe movements allows for all users to have appropriate travel behaviour and compliance with road rules.

1.3.2 Queensland Department of Transport and Main Roads

Technical Note TN191 Reducing pedestrian delays

Technical Note TN191 *Reducing pedestrian delays* provides additional information relevant to this guideline. This additional information will eventually be incorporated as a new section in TRUM Volume 1 Part 9.

***Traffic and Road Use Management* manual**

TRUM Volume 1 Part 9 is focused on traffic operations and includes guidance on traffic signals and the inclusion and design for pedestrians. Relating to pedestrians and traffic signals, TRUM also identifies:

- a desire for a minimum four seconds of pedestrian green time protection from vehicle movements in signal cycle times implemented as a delayed start to vehicle movements
- the potential use of smart pedestrian crossings at intersections to improve all traffic movements and safety, plus improve accessibility for mobility-impaired pedestrians, and
- the 98th percentile walking speed allows a longer clearance time for pedestrians to cross at traffic signals or locations with larger volumes of pedestrians.

Smart pedestrian crossings

Smart crossing treatments use standard traffic signal displays and sequencing with pedestrian detector systems and carriageway detectors (monitors pedestrians on the carriageway, starting the traffic phase once pedestrians are clear).

Smart pedestrian crossings use standard signal displays and sequence but add pedestrian detectors to improve pedestrian safety and efficiency for traffic. Carriageway detectors monitor the presence of pedestrians on the carriageway and extend the flashing DON'T WALK time (up to a pre-set maximum value) if necessary, to allow the pedestrian to clear the carriageway. Traffic operation is improved as the flashing DON'T WALK period is terminated early if not needed. Optionally, footpath pedestrian detectors can be used to cancel the pedestrian demand if the pedestrian crosses before the start of the green WALK period or decides not to cross and moves out of the detection zone.

Smart crossings are particularly valuable to more vulnerable pedestrians, such as visually impaired or elderly, who may move at a slower pace. Smart crossings can help reduce pedestrian delay by allowing shorter cycle times to be used.

Refer to TRUM Volume 1, Part 9 for additional information on smart crossings, including their benefits, design considerations and signal operations.

Road Planning and Design Manual

The RPDM Edition 2 Volume 3 Part 4 states that pelican crossings are not permitted and puffin crossings are typically not used in Queensland.

The RPDM Edition 2 Volume 3 Part 4A further identifies general considerations for the planning and design of intersections. Relating to pedestrians, these include:

- complex intersections require additional considerations to maintain safe operations – complex movements may require additional time or phases to clear the intersection and increase the total cycle time of the intersection
- the distance required for pedestrians to clear an intersection, should be as minimal as possible – longer distances will require a longer green phase and likely longer signal cycle
- in planning new intersections, the base case of traffic analysis should consider pedestrian crossings on all approaches and, in many cases, this will have minimal traffic effects – removal of a crossing on an approach can reduce pedestrian accessibility and increase delay, and
- the use of pedestrian crossings on left-turn slip lanes may dilute the Queensland road rule requiring drivers to give way to pedestrians crossing a slip lane, regardless of a formalised crossing or not – the preferred design treatment of left-turn slip lanes is outlined in the Department of Transport and Main Roads' (department) *Road Safety Policy*.

Road Safety Policy

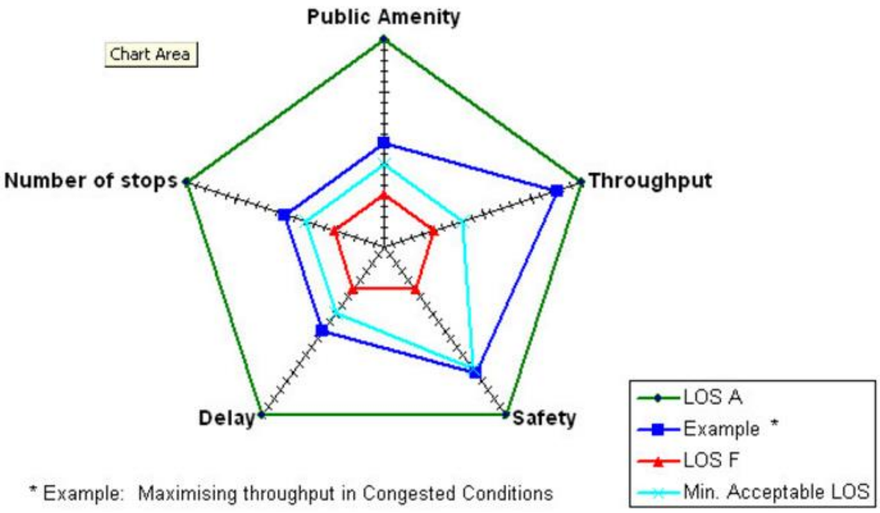
The *Road Safety Policy* (RSP) states the department will actively apply safety standards in the planning and design of road infrastructure and operational projects to manage safety risks and ultimately improve the road environment for all users. The RSP acknowledges the need to follow the Austroads Safe System framework and outlines the following safety standards relating to pedestrians and intersections:

- Projects will include provisions for pedestrians, cyclists and people with a disability, including footpaths and crossings.
- Pedestrian crossings are to be provided on all approaches at signalised intersections. Pedestrian crossing protection (delayed start to vehicle movements) is required.
- Unsignalised left-turn slip lanes should generally be avoided at intersections, unless signalised with pedestrian protection.
- Filtered green arrows for right turns are to be excluded unless justified by risk assessment.

Operation of Urban Traffic Signals Policy

The department's *Operation of Urban Traffic Signals Policy* (OUTSP) (email CyclePedTech@tmr.qld.gov.au to request a copy of this policy) focuses on the management of signal timings on urban arterial roads and provides guidance on signal timing priorities, based on achieving performance objectives. The OUTSP outlines how traffic signal timing can influence the performance of intersection qualities including amenity, delay, throughput, safety and stops, refer to Figure 1.3.2.

Figure 1.3.2 – Intersection performance objectives



The OUTSP identifies a minimum acceptable level of service for each performance objective and provides the following guidance on managing signals and allocating additional spare green time during specific time periods:

- peak periods – emphasis on the primary road network over other roads with signal times maximising throughput
- non-peak periods – emphasis on minimising stops on the primary road network and ensuring good green progression if there is a dominant flow in traffic, and
- low traffic volumes – emphasis on minimising delays and stops to all road users.

The OUTSP is specific to timing signals for vehicles; however, it does note that, where appropriate, the signal timings should be adjusted to give special consideration to other needs such as high volume or vulnerable pedestrians.

2 Current situation

2.1 Pedestrian delay, non-compliance and safety

Pedestrians are counted among the more vulnerable road users and care needs to be taken, so that they are not presented with unnecessary hazards, such as traffic signals that do not allow time to cross. Traffic signals can be considered by pedestrians as a delay point in their journeys and can potentially lead to unsafe behaviour when crowding occurs, or delays are perceived as excessively lengthy.

2.1.1 Pedestrian delays

Research completed on behalf of the Queensland Department of Infrastructure and Planning (refer to Section 5.5 of this guideline) and the City of Sydney, indicated pedestrians using key corridors within the Brisbane and Sydney CBDs experienced delays of 40% and 52% respectively of their total journey time along the corridor. For both research projects, pedestrians were spending almost as much time waiting at intersections as they were moving between intersections. As pedestrian trips within high-use areas tend to be relatively short in total travel time (approximately 10 minutes), any delays experienced by pedestrians can occupy significant proportions of their total journeys.

Pedestrians generally do not travel specific routes, but take the shortest, most direct and convenient alignment to reach their destinations. TRUM Volume 1 Part 9 identifies that, where pedestrians encounter lengthy wait times at intersections, then the level of pedestrian non-compliance increases. This can lead to pedestrians placing themselves in unsafe situations and undermines the potential safety benefits designed into an intersection.

2.1.2 Pedestrian non-compliance

Austroads *Guide to Traffic Management Part 12* identifies that traffic signals with excessive delays to pedestrians are likely to experience a higher degree of non-compliance. Research on behalf of the New Zealand Transport Agency (NZTA) found that pedestrian frustration increases after approximately 30 seconds of waiting; however, a pedestrian's reasonable expectation for acceptable delay ranges from 40–90 seconds. Pedestrians in Christchurch accepted a 38-second delay as reasonable, whereas pedestrians in Auckland accepted a 90-second delay as reasonable, as they acknowledged delay was inevitable, due to competition for road space.

Frustration in the amount of travel delay may lead to pedestrians crossing on a red phase which results in a higher level of non-compliance and safety risks. Any additional delay to pedestrians, such as extended cycle times, staged crossings, or crossing multiple legs to reach the desired destination, can lead to further non-compliance.

Environmental factors can influence pedestrian behaviour and non-compliance at traffic signals. Pedestrians waiting without weather protection, may decide to cross on a red phase to minimise their exposure to heat or rain.

TRUM Volume 1 Part 6 identifies an average pedestrian crossing signal compliance of 84% for single-staged crossings while multi-staged crossing compliance reduced to 69% for the first leg and 48% for the second leg. Additional academic research completed by the University of Queensland, supports the compliance rates identified in TRUM and further identified the following relationship between delays and compliance for pedestrians at traffic signals:

- as group size increases, so does compliance, indicating pedestrians are more likely to comply with signals if there are other pedestrians waiting
- as the width of a crossing location increases, so does compliance, indicating pedestrians are more likely to comply with signals where adequate width is provided across the road
- as the age of pedestrians increases, the level of compliance decreases, indicating children and teenagers are more likely to comply with signals than adults
- pedestrian compliance appears higher when a single leg crossing location is surrounded by health, shopping or educational land uses
- pedestrian compliance appears lower on weekends, compared to weekdays, and
- pedestrian compliance appears to increase as the perceived volume of traffic increases.

The research by the University of Queensland found that pedestrian delays should be kept to a minimum where possible and pedestrian compliance and, subsequently, pedestrian safety, are highest when the delay time is between 60–90 seconds. An additional finding of the research suggested that two-stage crossings should be avoided in locations with high pedestrian volumes such as near shopping centres or public transport stations.

2.1.3 Pedestrian safety at intersections

Brisbane City Council (BCC) completed a citywide pedestrian safety review to identify opportunities to improve safety for pedestrians throughout the community. As part of the project, BCC sought qualitative information from residents and visitors on issues affecting pedestrians. Some of the identified issues relating to pedestrian safety at intersections included:

- safe locations to cross
- drivers turning across a crossing, and
- extended wait times for a green WALK signal.

The University of Queensland research found that compliance levels and, subsequently, safety was influenced by a pedestrian's age, the number of pedestrians and surrounding land uses. Care should be taken when implementing pedestrian crossing treatments near educational facilities, to ensure a safe environment is created for pedestrians and drivers. Children unaccompanied by adults may find it difficult to see approaching vehicles and may step out onto a crossing. Likewise, drivers may have difficulty seeing young children, due to their size and may fail to stop.

2.2 Value of time assumptions

The traditional approach to intersection design has focused on vehicle movements and reducing queues and congestion. Intersections with multiple and complex movements, tend to have a higher cycle time to allow for vehicles to complete their movements without affecting intersection performance. Intersection assessments, specifically traffic modelling and economic modelling, tend to apply different assumptions on value of time.

For traffic modelling, different values of time are applied against the trip purpose and influence route choice. The main input for traffic modelling is volumes and, inasmuch as pedestrian volumes are included, the outputs tend to focus on optimising the intersection design and signal phasing for vehicles.

When reviewing assumptions behind economic and financial assessments, the user costs or value of time cost applied, traditionally varies between modes and trip purpose. Table 2.2 provides a comparison of the value of time associated with travel time per transport mode for various Australian and New Zealand authorities. The values presented in Table 2.2, represent the values used for transport modelling purposes and are based on travel for work purposes. These are general figures which can fluctuate based on the trip purpose and with different rates applicable for completing cost benefit analysis, however, the comparison shows that the time of motorised vehicles is valued higher than pedestrians.

Table 2.2 – Value of time by mode and authority for transport modelling ($/hour)*

	NZTA ($NZD)	NSW ($AUD)	ATAP ($AUD)
Car / motorcycle (driver)	$23.85	$17.72	$14.99
Car / motorcycle (per passenger)	$21.70	$17.72	$14.99
Public transport (driver)	N/A	$30.40	$25.72
Public transport (per passenger)	$21.70	$17.72	$14.99
Pedestrian / cyclist	$21.70	N/A	$14.99
Commercial vehicles^	$23.45	$30.96	$26.19

Source: NZTA; Transport for NSW; Department of Infrastructure, Planning and Natural Resources.

Notes:

*The values represented in Table 2.2 portray the values assigned for transport modelling purposes and based on the values assigned for travel for work purposes.

^The commercial vehicles' value represents the higher value between light commercial and heavy commercial vehicles due to the range presented for different commercial vehicles.

The *Australian Transport Assessment and Planning (ATAP) Guidelines* produced by the Australian Government's Department of Infrastructure, Transport, Regional Development and Communications, provides guidance and advice on completing economic appraisals of various transport modes. Relating to active transport, ATAP identifies the economic values for a range of benefits and costs, however, travel time costs are suggested to be 'mostly excluded'. ATAP is an updated version of the Austroads *Guide to Project Evaluation Part 4* (superseded) which recommended that the value of vehicle occupants be used for pedestrian travel. This advice has been removed from the ATAP.

Practitioners are encouraged to adopt a user approach to value of time assessments, particularly when investigating options and treatments for improving pedestrian delay at intersections in high-use pedestrian areas. Section 6 identifies several tasks that need to be considered when completing these investigations, including inputs in value of time assessments.

2.3 Economic cost of pedestrian time and delay

From an economic perspective, the value of time attributed to pedestrians and lost productivity from delays, can be significant and produce financial effects on local economies. Traffic modelling and assessment generally do not consider delays to pedestrians, but tend to focus on the delays to traffic, which can be a significant omission in areas of high pedestrian activity, given the pedestrian volumes relative to vehicle volumes.

The following research projects reviewed the cost of pedestrian delays:

- Auckland Council (2017) – A study of intersections along Queen Street, Auckland, found each pedestrian delayed for almost 30 seconds per cycle. This equals an annual cost up to $2.2 million per intersection, depending on pedestrian volumes or approximately $11 million along the Queen Street corridor. Additional information is in Appendix A.1.
- City of Melbourne (2018) – A study of the Melbourne CBD identified the effects of reducing the connectivity of the pedestrian network by extending waiting times at signalised intersections by 10%. The annual cost to the Melbourne CBD was estimated at $2.1 billion; equivalent to a 6.6% reduction in the CBD economy. Additional information in in Appendix A.2.

For high-use pedestrian areas such as CBDs and activity centres, the economic effects of delays to pedestrians can be substantial. For road authorities and practitioners, there are treatments available to assist in reducing pedestrian delays at traffic signals and improve overall journey travel times for pedestrians.

3 Pedestrians and traffic signals

3.1 Advantages and disadvantages of prioritising pedestrians

The *Planning Guidelines for Walking and Cycling* produced by the then-NSW Department of Infrastructure, Planning and Natural Resources, identifies that walking within centres should be the main basis of design when considering the street network. Using this focus for high-use pedestrian areas, road corridors and their associated intersections, should be an environment that encourages pedestrians to use the space. Referring to the Movement and Place Framework, prioritising the pedestrian level of service (place) over the level of service of other traffic movements (movement) may be an acceptable outcome for reducing delay in these situations.

The general advantages of reducing time delays and prioritising pedestrian movements at traffic signals include:

- reduced total pedestrian journey times
- increased pedestrian throughput and moving capacity
- less crowding of pedestrians at traffic signals
- improved pedestrian safety, due to greater compliance with traffic signals and reduced conflict time with vehicles
- an improved and safer environment for pedestrians with a disability
- some treatments can be cost neutral and implemented within the existing infrastructure and technology of the intersection, and
- no impact or a positive impact on access and safety – this is reported in Austroads' *Signal Management Techniques to Support Network Operations* where an impact assessment of different signal management treatments was completed against a base intersection, where all modes were considered equal priority. The result indicated the typical impact on access, safety and mobility in relation to other transport modes and road users, against a base treatment of equal priority for all users.

Some of the potential issues and disadvantages of reducing pedestrian delay could be:

- reduced mobility to other modes of transport such as private vehicles, public transport, cyclists and freight traffic as reported in Austroads' *Signal Management Techniques to Support Network Operations*
- less vehicle throughput and capacity / performance of the intersection which can lead to wider corridor and network performance issues, if vehicle congestion and queueing extend between intersections
- an increase in non-compliance of vehicle movements, particularly turning movements, and
- longer traffic queues and congestion for vehicles, or comparatively longer queues and congestion for vehicles, due to potentially less vehicle green time.

3.2 Treatments identified in existing guidance

Austroads' *Guide to Traffic Management Part 9* and *Signal Management Techniques to Support Network Operations* identify treatments that can be implemented to provide priority to pedestrians at traffic signals and, subsequently, assist in reducing pedestrian delays.

The treatments detailed in those Austroads publications include:

- exclusive signal phase for pedestrians
- exclusive scramble crossing or 'Barnes dance' phase – reduced pedestrian delays are likely when there is a high proportion of diagonal pedestrian movements, as this configuration allows two movements to be converted into one single movement
- double / half-cycling
- dwell on RED for all users, or dwell on WALK (green) for pedestrians – the implementation of the latter treatment in Queensland needs careful consideration of the safety issues and effects for each user; for example, implementation of this treatment along light rail corridors is considered unsafe
- extended clearance intervals – this treatment is considered part of the smart pedestrian crossings being rolled out in Queensland; refer to Section 1.3.2 of this guideline for additional information on smart crossings
- extended WALK / stretch WALK / rest in WALK – this treatment tends to be technically difficult to implement with STREAMS and additional consideration would be required
- reduced cycle lengths
- fixed demand – Austroads identifies that traffic signal controllers can be set to register a fixed demand for any pedestrian movement to operate each cycle, but should only be considered in high-use pedestrian areas where the cycle time is sufficient to accommodate all phases – a balance would need to be achieved between fixed cycle times and signal coordination; however, a lower cycle time may be more desirable than signal coordination
- puffin crossing – the RPDM Edition 2 Volume 3 Part 4 states puffin crossings are typically not used in Queensland; smart crossings provide the same time-saving benefits of a puffin crossing, without removing the far side pedestrian displays and the puffin specification includes a near side pedestrian display usually incorporated into the push button box – refer to Section 1.3.2 of this guideline for additional information on smart crossings
- isolated traffic controls at areas with high pedestrian demand
- pedestrian countdown timers – this treatment is incompatible with smart pedestrian crossings; refer to Section 1.3.2 of this guideline for additional information on smart crossings and TRUM Volume 1 Part 9 for information on pedestrian countdown timers
- reintroduction of pedestrian WALK (also referred to as double WALK phase)

- late start for vehicles (early start / leading interval for pedestrians – partially protected parallel walk) – this can also be applied as a restricted left turn; refer to TRUM Volume 1 Part 9 for information on pedestrian protection
- pedestrian parallel walk, and
- pelican crossing – the RPDM Edition 2 Volume 3 Part 4 states pelican crossings are not permitted in Queensland; refer to Section 1.3.2 of this guideline for additional information on smart crossings.

The Austroads publications provide a general description and rate these treatments and their effects comparatively to mobility, safety and access, using a scale for positive, neutral and negative impact against a baseline. Given the initial identification and assessment provided, this guideline will not duplicate this existing information and practitioners should refer to Austroads.

3.3 Additional treatments for consideration

As well as the treatments listed in the *Guide to Traffic Management Part 9* and *Signal Management Techniques to Support Network Operations*, the following options can be considered as additional treatments to reduce pedestrian delays at traffic signals:

- setting an optimal maximum cycle time (refer to Section 4 of this guideline), and
- green wave (refer to Section 5 of this guideline).

4 Setting an optimal maximum cycle time

4.1 Description

Setting an optimal maximum cycle time, refers to minimising or reducing the total cycle time to cater for the priority mode and supports the movement and place function of the intersection. For intersections with high pedestrian activity and volumes, the focus for an optimal maximum cycle time should be on pedestrian level of service and reduced waiting times.

The optimal maximum cycle time will likely vary, depending on the time of day; however, the cycle time should be optimised for the mode taking priority, based on the movement and place framework (refer to Section 1.2). For example, the maximum cycle time for a CBD intersection, may be higher during peak travel periods and lower in off-peak or evenings, to cater for the higher pedestrian volumes travelling to and from work.

The maximum allocated time needs to account for all phases within the intersection, including pedestrian green time, clearance time and through and turning movements. The optimal maximum cycle time for a signalised intersection could include reducing green times for vehicles, increasing green time for pedestrians, removing dedicated turning phases or a mix of other operational phases.

4.2 Advantages and disadvantages

Setting an optimal maximum cycle time and prioritising pedestrians at intersections should have the following benefits:

- more pedestrian green time each hour as phases are cycling quicker, allowing more opportunities for the pedestrian phase to be triggered
- less delay and waiting time for all users (pedestrians, cyclists, vehicles, public transport) between phases
- higher throughput of all users through an intersection
- reduced pedestrian crowding along high-use pedestrian corridors
- more opportunities for turning vehicles, due to more cycle phases overall within the hour period, and
- higher degree of compliance in pedestrian movements.

The following could be considered disadvantages of setting an optimal maximum cycle time focused on pedestrian level of service:

- reduced available time for complex phasing could lead to increased non-compliance
- reduced available time for left-hand turn movements which could lead to traffic using alternative routes that are less desirable, and
- increased delays comparatively for traffic as vehicles may require more than one green phase to pass through the intersection.

These disadvantages arise from the perspective of the vehicle occupants, from a different perspective, these disadvantages could be viewed as a positive motivator to encourage travel change. For people to change their travel behaviour, from single-vehicle occupants to multiple-vehicle occupants, or from driving to walking within high-use pedestrian areas, there needs to be clear benefits such as reduced delays or improved travel times. Congestion can be a motivating factor for improved activity centres, encouraging a change in travel behaviour and improved pedestrian transport corridors within CBDs.

4.3 Further guidance on maximum cycle times

Section 3 of Austroads' Guide to Traffic Management Part 4 outlines the Movement and Place Framework and identifies various movement and place strategies and where to focus priority for various road users, for example, to improve connectivity and flow of pedestrians, the focus needs to be on prioritising their use as places rather than used for moving vehicles.

Austroads' *Guide to Traffic Management Part 9* provides further information relating to maximum cycle times, specifically:

- Section 6.7.12 provides guidance on various signal timing purposes, settings required for safety and to minimise delay, and
- Table 6.8 identifies a typical range for maximum cycle time of 80–100 seconds for simple two-phase signals and 130–160 seconds for complex phasing.

4.4 Elements to assess

The following elements and investigations will assist in determining if setting an optimal maximum cycle time prioritising pedestrian level of service, is beneficial for an intersection with high pedestrian activity:

Maximum cycle time – There is no set time recommended for a maximum cycle time (refer to Section 4.3 of this guideline for Austroads' range of times); therefore, site-specific analysis of the road network, volumes and environmental factors will be required to determine an appropriate maximum cycle time.

Posted speed limit – A reduction in the posted speed limit to slow traffic between intersections, may assist in reducing wait time effects on vehicles. A lower speed limit, coupled with reduced cycle times and the spacing between intersections, could improve flow of traffic; however, the impacts to overall intersection performance and pedestrian and vehicle throughput needs to be considered.

Traffic modelling – Site-specific modelling of the intersection, corridor or network may be required to reflect the actual situation and likely changes to the travel patterns and route choices of users. The following information should be required for traffic modelling to be effective:

- *pedestrian volumes* – traffic counts will be required to identify the volume of pedestrians and their movements, and
- *signal timings and optimisation* – current signal timings to test the current situation and performance of the intersection will need to feed into the traffic model used to replicate actual operations.

Site assessment – Observations of user (pedestrian, cyclist and vehicle) behaviour will ascertain any compliance or safety issues that are occurring. Critical issues may require considering alternative or additional treatments, along with setting an optimal maximum cycle time.

Review of performance measures – Performance measures need to be reviewed to determine the existing level of service provided to different modes. The Movement and Place Framework is an appropriate framework to identify the desired level of service of different modes and the necessary adjustment required to optimise the maximum cycle time to prioritise pedestrian level of service.

Right-turn conflicts – An existing intersection with a filtered right turn may have additional conflicts with pedestrians and opposing traffic movements if an optimal maximum cycle time for pedestrians results in a reduction in green time for vehicles. The department's *Road Safety Policy* excludes filtered green arrows for right turns which would remove this conflict. Any changes to intersections will need to comply with the *Road Safety Policy*.

Network planning – Traffic signals in high-use pedestrian areas, such as a CBD, will require coordination to reduce pedestrian delays. The reduced or increased cycle time may affect adjacent intersection performance, depending on intersection spacing. A network approach is required to modify the cycle times so the same cycle times or double cycle times are implemented across the corridor.

4.5 Considerations for implementation

This section identifies factors that authorities need to consider when seeking to set an optimal maximum cycle time at signalised intersections. These are not designed to be an extensive checklist but aim to identify issues to consider prior to implementation.

4.5.1 Technical considerations

There are no technical barriers to setting an optimal maximum cycle time.

Austroads' *Guide to Traffic Management Part 9* notes traditional vehicle-actuated controls tend to use a maximum green time setting and not a maximum cycle time setting. The timing plans within the traffic signal software used to manage most intersections in Queensland (STREAMS), can be modified to be operated based on set timing and can be coordinated between adjacent signals (refer to Section 5 of this guideline). This may be required in high-use pedestrian areas, where the high pedestrian volumes may not be detected.

For signals to implement a lower cycle time, road operators need to set an appropriate reduced maximum green time for vehicle-actuated operations in the controller and change the green time settings in the STREAMS time of day plans. This approach will allow road operators to reduce green time and optimal maximum cycle time prioritising pedestrian level of service.

4.5.2 Physical considerations

There are no physical barriers to prevent setting an optimal maximum cycle time prioritising pedestrian level of service.

Additional intersection enhancements, such as kerb build-outs or ramps, could further improve the pedestrian environment. Additional infrastructure enhancements for pedestrians would need to be considered case-by-case and be designed to address site-specific intersection characteristics and pedestrian activity.

4.5.3 Social considerations

The setting of an optimal maximum cycle time for prioritising pedestrians may affect drivers, increase vehicle delays and cause driver frustration, particularly if queues do not clear an intersection every cycle.

Changes to vehicle movements may be viewed negatively by the community and generate complaints. Road operators will need to have clearly-defined objectives supported by policy to provide a sound rationale for the implementation of a lower maximum cycle time and prioritising pedestrian movements.

4.5.4 Environmental consideration

There are no environmental barriers to prevent setting an optimal maximum cycle time prioritising pedestrian level of service.

Situations of high traffic volumes at intersections may lead to vehicles waiting more than one green cycle, which could cause significant additional emissions from the stop / start of traffic and increased congestion.

4.6 Case study: City of Perth cycle time study, Perth, Western Australia

The City of Perth and Main Roads Western Australia reconfigured the signal phasing of intersections throughout the Perth CBD, to improve the environment and facilities for pedestrians, improve accessibility and reduce delays to both pedestrian and vehicular traffic. The goal of these changes was to improve walkability and encourage walking as the preferred mode of travel in the Perth CBD. This goal was achieved by reducing the maximum cycle time and introducing double WALK pedestrian phases (also known as reintroduction of pedestrian WALK).

Pedestrian count data and signal cycle timing data were used as inputs into a traffic model, to test the existing base scenario against a scenario where signalised intersections used a maximum cycle time of 120 seconds for operations, along with double cycling of intersections where possible. The model showed implementing a maximum cycle time would likely reduce pedestrian and vehicle delay throughout the CBD and improve traffic speeds with minimal effect on public transport operations.

Following changes to the maximum cycle times, intersection performance was compared to performance prior to the timing change to identify the improvements to traffic and pedestrians. The review of performance indicated the following actual network improvements:

- total travel time reduced by 5% in the AM and PM peak travel periods
- delays for people walking reduced by 11% in the AM peak and 10% in the PM peak travel periods, and
- reduced cycle times (that is, reducing the cycle times to 120 seconds) benefited pedestrians with minimal effects on buses and general traffic.

This study provides a practical example of prioritising pedestrians at signalised intersections, without providing a negative effect on vehicles.

4.7 Case study: Signal cycle times in cities

Austroads' *Guide to Traffic Management Part 9,* indicates a typical range for maximum signal cycle time settings of 80–100 seconds for simple two-phase signals and 130–160 seconds for more complex signal configurations. Some of the intersections classified as 'complex' by Austroads include seagull T-intersections, signalised roundabouts, railway level crossings and diverging diamond interchanges.

Research on pedestrian behaviour and compliance with signalised intersections completed by the University of Queensland, recommended a maximum traffic signal cycle time of 120 seconds. 120 seconds can be considered a desirable maximum traffic signal cycle time; however, appropriate consideration of the Movement and Place Framework is required to confirm the priorities for people and goods at each intersection.

A review of available information, data and reports has produced the following list of signal cycle times implemented in various locations across Australia.

- Brisbane CBD: 90 seconds
- Brisbane (general): 60–160 seconds
- Mackay council-controlled roads: 90–120 seconds
- Mackay state-controlled roads: 120–140 seconds
- Melbourne: 90 seconds with 120 seconds for complex signals
- Canberra: 110 seconds
- Perth: 120 seconds
- Cairns: up to 140 seconds
- Townsville: 110–140 seconds, and
- Queensland state-controlled roads: usually between 50–150 seconds.

Note: These times are the higher cycle times identified by the research source and may have changed since the source data was published: see *Active transport users guidelines references* for research source details.

Most of the urbanised centres fall within the simple two-phase cycle times recommended by Austroads, whereas the regional centres and some state-controlled roads within Queensland are at the longer end of the complex signal timing recommendation by Austroads. This may be due to the urbanised nature of the road network in city centres requiring simple traffic movements, whereas regional centres and state-controlled roads are more likely to have a dominant through movement at intersections.

5 Pedestrian green wave

5.1 Description

The concept of 'green wave' refers to coordinating adjacent traffic signals or linking several signals along a corridor so that specific road users are met with consecutive green signals as they approach, without the need to stop or be delayed from red signals.

Traditionally, this concept has been applied to general traffic and public transport movements along key corridors during peak travel periods; however, the concept can also be applied to active travel modes. Green waves can be applied along high-use corridors so that pedestrians travelling at a certain speed along the entire corridor receive a green phase at each intersection with no delay.

5.2 Advantages and disadvantages

Some of the advantages a green wave could provide, include:

- continuous connectivity for pedestrians along the corridor
- increased pedestrian throughput and moving capacity
- increased pedestrian compliance with traffic signals along the corridor and reduced conflicts / crashes with vehicles from pedestrian non-compliance
- reduced delays to pedestrians from waiting at traffic signals with red signal phases
- potential for reduced delays and idling time for vehicles travelling along the green wave corridor via improved signal cycle times and potentially lower vehicle speeds, and
- reduced pedestrian exposure to environmental elements such as inclement weather, harsh sunlight, rain and storms; for example, a walk through a Queensland CBD could translate to five–10 minutes of direct exposure to sunlight, due to delays at traffic signals, whereas a green wave can reduce and limit this exposure.

Some of the disadvantages and issues a green wave could manifest include:

- potential for added delays to vehicles turning at intersections along the green wave corridor
- increased delay to vehicles and traffic flow on side streets perpendicular to the green wave corridor, and
- delays to pedestrians moving faster or slower than the designed pedestrian speed on the green wave corridor.

5.3 Further guidance on coordination of traffic signals

Austroads' *Guide to Traffic Management Part 9* provides further information relating to the coordination of traffic signals, specifically:

- Section 6.9 provides guidance on the coordination of traffic signals, including objectives and principles of coordination, design considerations, types and methods of coordination, and developing coordination plans
- Section 6.9.6 provides specific information on coordinating signals and offset strategies for cycle times, and
- Section 6.13.2 further identifies information relating to the commissioning of coordinated traffic signals.

5.4 Elements to assess

The following elements and investigations need to be considered when implementing a pedestrian green wave along a corridor for the signal coordination to be effective:

Volume of pedestrians – There needs to be a high volume of pedestrian activity to offset the potential effects on and delays to traffic on side corridors. Suburban locations are unlikely to generate sufficient pedestrian volumes to warrant a green wave, whereas major activity centres and CBDs will attract high pedestrian volumes.

Travel destination – There needs to be strong destination or land use attractor to encourage a high volume of pedestrians to travel in the same direction. If attractors are dispersed, pedestrian travel is likely to be dispersed as well. Potential opportunities include from public transport stations to educational facilities or CBD.

Conflicts with other modes – A corridor with several transport modes can potentially affect the flow of all transport users, such as the on time reliability of public transport.

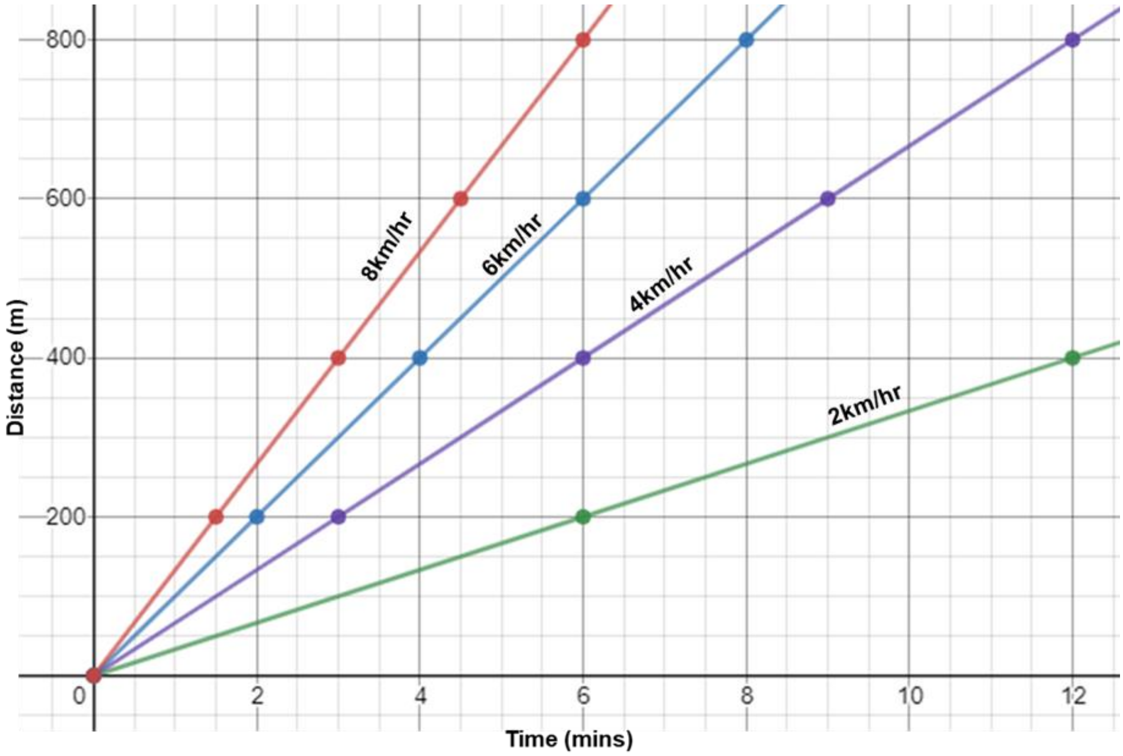
Quality of footpath – Sufficient width is needed to support the higher volume of pedestrians travelling in the same direction, as well as a clear path, free from obstacles or obstructions.

Signal coordination – The selected corridor needs to include traffic signals on the same software coordination system.

Intersection type – The selected corridor needs to include traffic signals on all intersections; otherwise, the continuous green wave may be difficult to achieve. Alternately, if an intersection midway along the corridor is not signalised, it would need to include a priority crossing, such as a wombat or zebra crossing, to ensure continual travel for pedestrians.

Speed of travel – Pedestrian travel at varying speeds and their individual mobility concerns, may further reduce the speed of travel. It is important to consider varying speeds of travel and the distance between intersections so enough green time is provided for pedestrians and other road users. The use of a time / distance diagram will assist in planning cycle times at intersections along the corridor. Figure 5.4(a) shows an example time / distance diagram and the distance and time pedestrians at various walking speeds can travel.

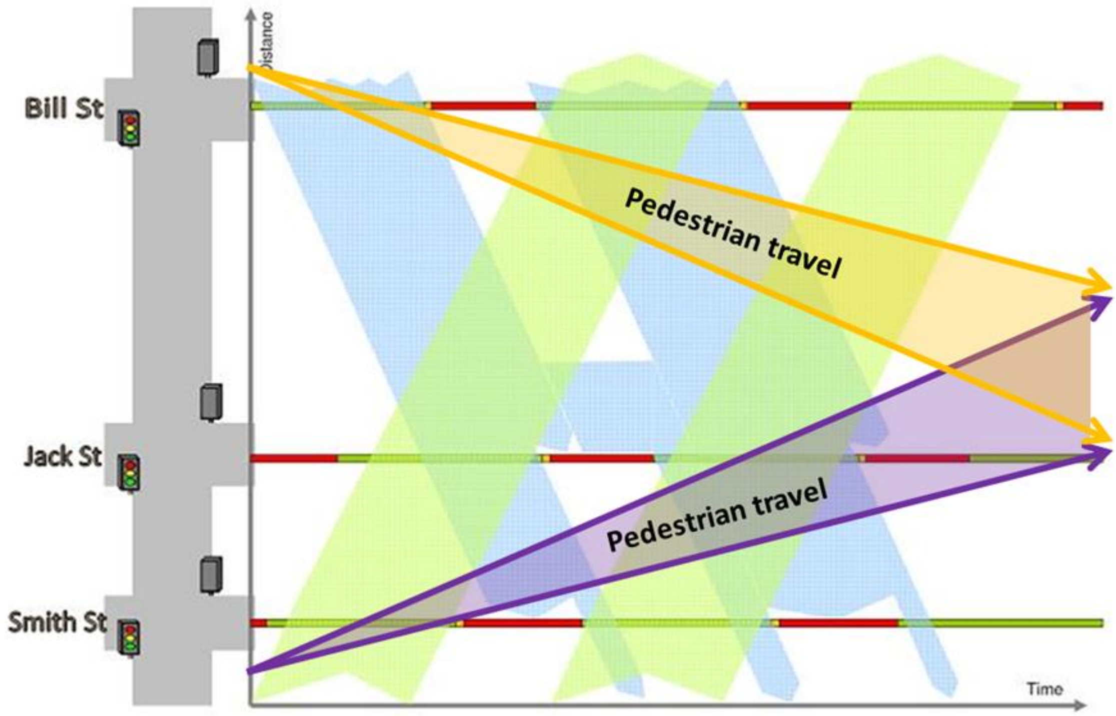
Figure 5.4(a) – Time / distance diagram example for different pedestrian speeds



Source: Transport and Main Roads

Figure 5.4(b) shows a visualisation of coordinated traffic signals and how a pedestrian green wave could operate.

Figure 5.4(b) – Example traffic signal coordination and pedestrian green wave



Source: Transport and Main Roads

5.5 Considerations for implementation

This section outlines elements that authorities should consider when identifying a suitable corridor to implement a pedestrian green wave. These are provided to guide the planning and design process to ensure key aspects for the success of the green wave have been considered.

5.5.1 Technical considerations

The implementation of a pedestrian green wave has one recognisable technical limitation, being the controller software used to coordinate traffic signals along a corridor.

The Sydney Coordinated Adaptive Traffic System (SCATS) is a dynamic program that modifies cycle times and coordinates traffic signals based on real-time data. SCATS may struggle to provide a continual coordinated green wave for pedestrians, unless a fixed timing approach is adopted which then negates the real-time adaption for other modes.

For Queensland, the state road authority and most of the local government authorities use STREAMS to coordinate traffic signals, which can be used for coordinating a pedestrian green wave. Adjacent traffic signals need to be connected via the same management software to enable a pedestrian green wave.

5.5.2 Physical considerations

There are no physical barriers to prevent the implementation of a pedestrian green wave; however, the distance between intersections along the corridor, is key to continual pedestrian movement. Intersections spaced too near or too far may not allow continual pedestrian movement without delay; therefore, the intersection spacing and associated intersection cycle times need to be investigated for a green wave to occur.

Road authorities should ensure the physical environment of the footpath is clear of street furniture and a clear and safe path is provided between intersections. Trimming vegetation and relocating seating or other street furniture that may hinder pedestrian traffic (particularly users with low mobility or visual impairments), should be considered.

5.5.3 Social considerations

Depending on the signal cycle times, the implementation of a green wave may affect the traffic flow on the main road and side streets of the green wave corridor. With a potential change in cycle times, traffic users on the main road could experience a loss of coordination, with cycle times tailored for a pedestrian green wave, whereas traffic users on the side streets may experience a longer delay period. This may cause users on both roads to experience frustration. Any potential change should be scenario tested and modelled prior to implementation.

The coordination of traffic signals may require financial considerations from road authorities which may not have the resources available. Signal coordination along corridors may require dedicated resources to monitor and manage signals and phases.

5.5.4 Environmental considerations

There are no environmental barriers to prevent the implementation of a pedestrian green wave.

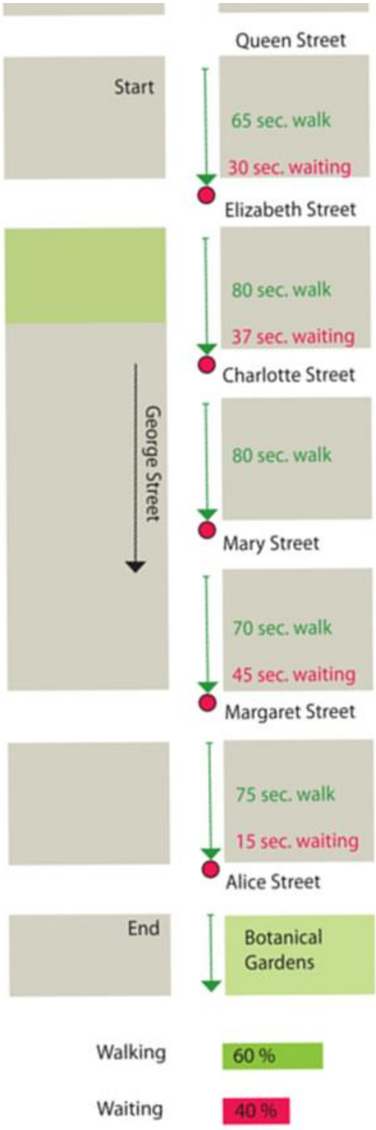
5.6 Case study: George Street, Brisbane, Queensland

The then-Queensland Department of Infrastructure and Planning undertook research into developing a people-oriented vision for Brisbane that would encourage increased walking and cycling activity. The project completed an investigation along George Street in the Brisbane CBD between the Queen Street Mall and City Botanic Gardens / Queensland University of Technology (QUT) to demonstrate the existing delays experienced by pedestrians as a proportion of total travel time.

As illustrated in Figure 5.6, this investigation found:

- pedestrians were moving 60% of the time
- pedestrians were waiting at intersections 40% of the time
- very short pedestrian green times at signals made it difficult for pedestrians to meet a green signal and pedestrians would likely be delayed at each intersection on the corridor
- long waiting times for pedestrians was influenced by a car-prioritised road system, and
- pedestrians tended to walk in platoons, which causes further congestion and delay to pedestrians by having to avoid conflict with other pedestrians.

Figure 5.6 – Pedestrian walking and waiting time along George Street



Although this case study demonstrates the issue of pedestrian delays, the key learnings applicable to implementing a pedestrian green wave include:

- there are two dominant land uses at each end of the corridor, being QUT and the Queen Street Mall, with its associated bus station
- there are dominant flows of pedestrian traffic to QUT in the morning and to the Queen Street Mall in the afternoon
- pedestrian volumes along this corridor could be considered high, as students access education continually across the day
- pedestrians, cyclists and vehicles are the main modes of travel along the corridor, and
- the footpaths are wide in many areas.

5.7 Case study: Albert Street green wave corridor, Melbourne, Victoria

The City of Melbourne completed a trial of a green wave corridor for cyclists in September 2019, with the green wave permanently implemented. The green wave was first trialled due to observing an increase in cyclist crashes and conflicts with other road users. The intent of the trial was to reduce cyclist speed along the corridor and, in turn, improve safety while reducing travel time delays.

The green wave corridor is in East Melbourne along Albert Street, between the intersections with Hoddle Street and Lansdowne Street. The corridor is over one kilometre in length and has six signalised intersections for traffic to traverse.

The implementation of the green wave along the corridor, saw an improvement in cyclist travel times of approximately one minute, due to reduced delay and waiting at the traffic signals.

Although this project is focused on cycling, there are transferrable key learnings that can be applied to a pedestrian context. These include:

- Traffic signal cycle times need to be as low as possible, without affecting traffic movements in the opposite direction. If cycle times are increased, this can further delay all road users
- The corridor improves with a peak travel direction. Having multiple destinations for road users can make the green wave difficult to implement, as there are competing directions. If users have a common destination (such as a public transport node, education facility and so on), a dominant movement and direction can be prioritised.
- The corridor needs to have less / low volumes of public transport. Corridors with high volumes of public transport can be affected negatively, due to the lower cycle times which may cause further delay to public transport.

6 Other considerations

The following elements should be considered by practitioners and road authorities when planning or designing new signalised intersections or making changes to existing signalised intersections to provide priority to pedestrians and reduce pedestrian delays.

Left-turning traffic

Austroads' *Guide to Road Design Part 4* suggests that, where pedestrian flows are significant at signalised intersections, it may be appropriate to have left-turning traffic pass through the signals, rather than provide a left-turn island and roadway. In these situations, an alternative location for the left turn would need to be supplied, without causing undue additional travel and delay to vehicle movements.

Pedestrians, particularly those more vulnerable such as the visually impaired, prefer for left-turn slip lanes to be removed to improve accessibility and safety. This is supported by the department's *Road Safety Policy* (refer to Section 1.3.2 of this guideline), which identifies that unsignalised left-turn slip lanes should be avoided at intersections, unless signalised with pedestrian protection.

Intersection evaluation

Different priority treatments can affect other road users, including general traffic, freight and public transport. The benefits to and effects on all road users, need to be considered against site-specific information and evaluated prior to any changes at traffic signals. A generic response to all signalised intersections is not possible or appropriate; therefore, site-specific evaluations are required to respond to any unique characteristics and to identify appropriate treatments.

Once site-specific investigations have been completed and options identified, engagement with key stakeholders and the general public is essential. Intersection users and asset managers will have information relevant to the operation of the intersection and potential issues and concerns. Consultation with stakeholders and the public can provide further support for the preferred treatments.

Traffic count data

Traditionally, intersection modelling has focused on vehicle volumes and intersection design to improve vehicle traffic flows. This approach can be detrimental to path users, with increased delay, safety risk and non-compliance. In high-use pedestrian areas such as CBDs, pedestrians can make up a high proportion of total users at intersections; therefore, traffic counts should be comprehensive and encompass all road users, including pedestrians, their turning movements, direction of travel and changes to these throughout the 24-hour period. Traffic signal systems such as STREAMS capture only the number of times a push button is activated, with a maximum of once per cycle and do not count the volume of pedestrians. Specific pedestrian traffic surveys will be required to capture volumes and direction of travel to obtain the necessary data.

Random pedestrian patterns

Austroads' *Guide to Traffic Management Part 4* indicates pedestrians do not confine themselves to specific routes or alignments but will follow the shortest and most direct path requiring minimal effort and the quickest travel time between their origin and destination.

Pedestrian movements at intersections are variable and can change randomly in response to the built environment or streetscape environment. Key destinations, such as stadiums or public transport hubs, can experience a peak in pedestrian activity for short periods of time, whereas high-use pedestrian areas, such as CBDs, experience higher pedestrian activity over longer and regular periods of time.

Value of time assessments

In high-use areas, traditional modelling assumptions can lead to intersections, infrastructure and cycle times designed to cater for motorised transport which places less importance on pedestrians. A user approach to modelling and economic assessments should be applied where each user, regardless of travel mode, is considered equal. This approach is applicable in high-use pedestrian areas, where the volume of pedestrians can be equal to, or higher than, the volume of motorised traffic.

Exclusive pedestrian phases

The New York City Department of Transport completed a study investigating exclusive phases for pedestrians at signalised intersections, with a focus on improving safety. The study found implementing an exclusive pedestrian phase increased pedestrian delays, compared to traffic signals that operated a concurrent pedestrian and vehicle phase. This study acknowledged exclusive pedestrian phases can be an effective treatment to improve safety and reduce conflicts. Additional information on this case study is included in Appendix B.1.

After identifying a high number of pedestrian crashes between 2013–2018, BCC implemented several pedestrian safety treatments within the Brisbane CBD including exclusive pedestrian phases along Albert Street. The intent of the exclusive pedestrian phase was to boost pedestrian safety and reduce pedestrian wait times at the intersection. BCC identified almost 80% of all traffic in the morning peak comprised pedestrians at the Albert Street and Charlotte Street intersection.

Exclusive pedestrian phases can be an effective treatment to reduce conflicts between pedestrians and vehicles and reduce pedestrian waiting times at intersections; however, careful site-specific investigations are required to identify intersection priorities and manage effects on users.

Long term considerations

Making changes to signal operations will eventually reach an optimal point, where further attempts to reduce pedestrian delay cause safety consequences to other modes or affect the overall performance of the intersection. When undertaking an assessment of an intersection, road authorities and practitioners should consider the intersection's long-term requirements such as infrastructure treatments or grade separation, as well as the potential interim solutions in this guideline.

The costs of accidents and time delays to both pedestrians and vehicles, should be considered against any construction costs to improve the intersection; for example, a grade separated crossing may have a lower construction cost then the potential costs from accidents and time delays imposed by an at-grade crossing. Taking a long-term approach to the intersection with interim or staged improvements can be an effective way of managing all users at an intersection.

This long-term approach is also important for major events, which can attract a high volume of pedestrians to one location within an activity centre. Upon completion of the event, pedestrian desire lines can be concentrated to specific locations such as licensed premises or public transport nodes. In these situations, an assessment of event pedestrian traffic is required to prevent major effects or delays to the surrounding road network and appropriate intersection treatments selected.

To illustrate, there is a strong pedestrian desire line between Suncorp Stadium and Milton rail station in Brisbane before and after sporting events. During the redevelopment of the stadium in 2001–2003, the movement of pedestrians between these two locations was considered. Given the extremely high volume of pedestrians, it would be inappropriate to consider at-grade crossing solutions as the delays and crowding / congestion to all users would be impractical. To accommodate the high volumes, a grade separated overpass was implemented to connect the two locations without adversely affecting other transport network users.

Appendices

Appendix A – Case studies for the economic cost of pedestrian time and delay

A.1 Case study: Auckland, New Zealand

Auckland Council commissioned a study to review pedestrian delays at signalised intersections along Queen Street. The intersection of Queen Street and Victoria Street (scramble crossing) and the intersection of Upper Queen Street and Karangahape Road (two-phase crossing) were analysed to quantify the pedestrian delays and identify the economic effects resulting from the delay. The study identified pedestrian volumes, movements and the time spent waiting for a green phase at each intersection between 12pm–1pm on a weekday. The study found:

- 7697 pedestrians using the Queen / Victoria intersection with a delay between 26 – 29 seconds; an average delay of 27 seconds per pedestrian, and
- 1892 pedestrians using the Upper Queen / Karangahape intersection with a delay between 30 – 55 seconds; an average delay of 37 seconds per pedestrian.

The delays identified for the observed hour were annualised to identify the total time lost, due to waiting at each intersection. The value of travel time rates identified by the NZTA, were applied to the annual time delay values and annualised to produce an estimated cost.

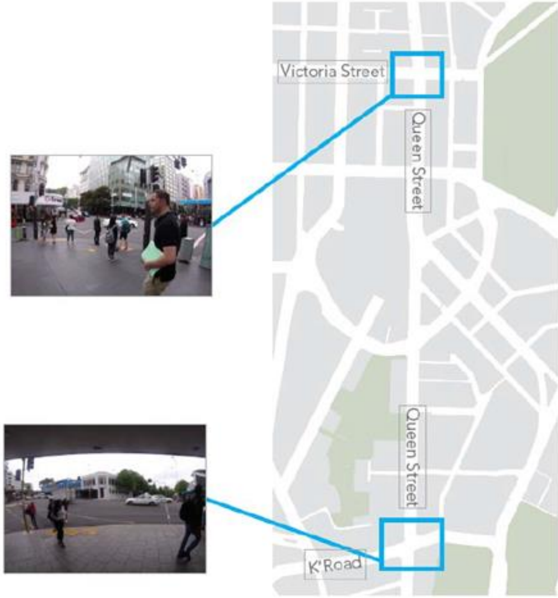
The annual economic cost of delay for pedestrians at each intersection was $2.2 million for Queen / Victoria and $714,000 for Upper Queen / Karangahape.

The study applied an optimised signal scenario for each intersection by reducing the average delay by seven seconds at Queen / Victoria and 17 seconds at Upper Queen / Karangahape to test an average delay of 20 seconds per pedestrian. The change in average pedestrian time resulted in an annual cost of delay of $766,000 at Queen / Victoria ($1.5 million saving) and $336,000 at Upper Queen / Karangahape ($370,000 savings).

The study found that small changes in intersection cycle times and optimising traffic signals to consider different movements that included pedestrians, can have positive benefits on pedestrian delays and reduce lost productivity. This is particularly significant in city centres where pedestrian volumes can be higher than vehicle volumes.

Figure A.1 shows the Queen Street study area.

Figure A.1 – Queen Street study area



A.2 Case study: Melbourne, Australia

The City of Melbourne's *2030 Transport Strategy* completed research into the issues, challenges and options to improve travel for all modes. Pedestrian delays at intersections, within the Melbourne CBD, was an acknowledged issue. The City of Melbourne identified pedestrian delays are influenced by signal management, cycle times, walk duration and the need to call a pedestrian phase.

For the Melbourne CBD, pedestrian traffic makes up approximately 66% of internal trips and results in high volumes of pedestrians using footpaths to travel through the CBD. The City of Melbourne reports the following approximate daily volumes for pedestrians and vehicles in its CBD:

- Russell Street and Bourke Street – 25,000–30,000 pedestrians, 24,000 vehicles.
- Collins Street and Collins Place – 20,000 pedestrians, 16,000 vehicles.
- Collins Street between Spencer Street and King Street – 40,000 pedestrians, 4000 vehicles.
- Elizabeth Street and Flinders Street – 35,000 pedestrians, 3000 vehicles.

A travel time analysis was completed for a scenario where pedestrian delays at signals were increased by 10%. This additional time delay was valued at approximately $2.1 billion, equivalent to a 6.6% decrease in the CBD economy.

To address challenges and create a more 'walkable' CBD, City of Melbourne proposed the following concepts:

- developing new shared or pedestrian-only streets with a high amenity and safe walking environment, without conflict with vehicles or delays at intersections
- optimising the distribution of signal time, shortening overall cycle times and allocating cycle time to better reflect the relative volumes of pedestrians and vehicles using an intersection
- reducing the physical distance required to cross at an intersection through kerb build-outs, and
- constructing new formal pedestrian crossings to reduce wait times and improve connectivity and safety.

Appendix B – Project case studies

B.1 Case study: New York City, USA

New York City commissioned a study investigating exclusive pedestrian phases (scramble crossing / Barnes dance) for signalised intersections, with a primary focus on improving pedestrian safety. The study found the conversion of signalised intersections, from concurrent pedestrian / vehicle phases to include an exclusive pedestrian phase, increased pedestrian delays and non-compliance from pedestrians. In areas of high pedestrian activity, there was crowding and disruption to the footpath leading to the intersection.

The study found implementing a dedicated pedestrian phase increased pedestrian wait times of between four to nine seconds per pedestrian and delay to cyclists, vehicles and public transport by seven to nine seconds. One of the key outputs for the study, was acknowledging that exclusive and dedicated pedestrian phases can be an effective tool to improve safety by reducing pedestrian–vehicle conflicts; however, each intersection needs to be considered as well as the effects on all users.

The study further identified alternative treatments for pedestrians at signalised intersections, which are already identified in Austroads and included in Section 3.2 of this guideline. Those relevant to pedestrian delays include:

- leading pedestrian interval traffic signal phasing – providing pedestrians with a head start prior to vehicles commencing on the concurrent movement (left-turn and straight moving vehicles); this provides additional time to cross without conflict and minimises wait time
- split-phase leading pedestrian interval traffic signal phasing – providing pedestrians with a head start prior to vehicles commencing the left turn only; this provides similar benefits and issues as the leading pedestrian interval traffic signal phasing
- split-phase traffic signal phasing – separates (splits) pedestrian and turning traffic into separate phases to provide full protection for pedestrians; this tends to provide less crossing time for pedestrians
- restricted movements – banning turning movements so pedestrians have a continual green phase and a longer phase to cross; however, this can affect other road users if there is no alternative turning location along the corridor, and
- kerb extensions – provide additional space for pedestrians to wait and reduce the distance required to cross the road.