

Review of Signal Operations for Pedestrians in the City of Melbourne

Report on the Action Stream of Draft Walking Plan 2014-17



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19 April 2014

Reference: Z13-05

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Executive Summary

The recommended actions for the City of Melbourne Walking Plan 2014-17 are:

Action stream relating to signal operations:

- **Use SmartRoads tools to assess pedestrian delay at intersections across the city and review SCATS data within the CBD to reduce pedestrian delay where practicable.**
 - Review marriage chains to encourage shorter cycle times
 - Review cycle time control to encourage shorter cycle times in light to medium traffic conditions
 - Review SCATS control of Walk termination to increase the Walk time within the allocated phase time where the effect on left turning traffic is tolerable
 - Extend this review outside the CBD in future years
- **Expand the implementation of auto-introduction of Walk signals at intersections in the area shown in Figure X, where compatible with prevailing signal timings.**
 - Within the CBD, auto-introduction generally operates from 5:30 am to 12:30 am and operates at all times for crossing the narrow 'Little' streets
 - Outside the CBD, it is recommended to operate according to the prevailing phase time or cycle time
 - Auto-introduction should not be implemented at pedestrian operated signals
- **Implement a clearance countdown display at the intersection of Flinders St and Elizabeth St and evaluate its performance.**
 - Wait countdown timers are not recommended
- **Work with VicRoads to install pedestrian lanterns and audio devices at those CBD crossings that do not already have them.**
 - Applies to the crossings across 'Little' streets at about 16 intersections in the CBD
 - Push buttons are not required as the Walk is automatically introduced at all times

Other action streams:

- **Widen crosswalks within the CBD that are less than 4 m wide.**
 - This addresses crowding on corners and makes the crossings more comfortable
- **Build kerb outstands at CBD intersections where there is space to do so.**
 - This reduces crossing distances and provides more space for pedestrians to wait
- **Relocate footpath furniture away from corners at busy intersections.**
 - This only applies at a few locations where furniture impedes the crossing and moving it is practical
 - This is important for pedestrians with a visual disability
- **Encourage police to enforce vehicles blocking intersections and crossings.**
 - Enforcement is the best approach to minimise this problem
- **Continue the program to retrofit audio-tactile devices at all traffic signals.**

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1. Background

The City of Melbourne has developed a draft **Walking Plan 2014-17** which includes an Action Stream relating to signal operations. This covers the timing and facilities for pedestrians at traffic signals.

This report is a review of those proposed actions as part of the Walking Plan draft dated 23rd October 2013. It provides comment and advice in relation to pedestrians at traffic signals within the City of Melbourne, both at intersections and mid-block. It also considers how reduced speed limits may affect traffic signal operations and the way they are programmed.

2. Purpose

The purpose of this review is to provide comment and advice in relation to the 5 action areas as currently proposed in the draft Walking Plan, namely:

- Reducing delay to pedestrians at signals
- Automatic introduction of pedestrian green displays at signals
- Providing an early start for pedestrians ahead of vehicle displays
- Providing pedestrian countdown timer displays
- Providing pedestrian lanterns at those CBD intersections that currently do not have them.

The review also sets out to achieve the following:

- Suggest and assess other practical measures or tools that could improve pedestrian level of service at traffic signals.
- Compare the benefits, trade-offs and appropriate application of these measures, and how they might be integrated with one another.
- Outline how these measures can be combined and what advantages and disadvantages would be generated. Consider the application at different times of the day and different traffic conditions.
- Recommend an appropriate Walking Plan action for each of these 5 action areas, with a view to achieving the most for pedestrians, but mindful of practicality, affordability and the effect of the proposal on other stakeholders.
- Recommend the geographical area or other criteria which would determine the extent of implementation of each proposed action.
- Analyse data from VicRoads to determine a meaningful measure for each signal site that is a reasonable reflection of average pedestrian delay. Recommend to Council officers what data they should be asking VicRoads to provide to achieve this. Discuss the data with VicRoads staff.

3. Reducing delay to pedestrians

This action area is probably the most important recommendation within the signal operations part of the draft Walking Plan but it is also the least well defined.

Pedestrian delays can be reduced through signal operations by the following means:

- reduce cycle times
- change phase splits
- increase Walk times within the allocated phase times

These could be used in combination.

Cycle times

Reducing cycle times can reduce average and maximum waiting times by the amounts shown in Table 1.

Table 1: Effect of cycle time on pedestrian delays

Cycle time	100 s	90 s	80 s
Walk time	30 s	25 s	20 s
Average pedestrian delay	24.5 s	23.15 s	22.5 s
Maximum pedestrian wait time	70 s	65 s	60 s

These values are calculated for demonstration purposes on the assumption of fixed time signals, with only two phases and equal phase splits. The calculations also assume random arrivals and no queuing of pedestrians on footpaths. About 60% of the CBD intersections have more than two phases (with extra phases being provided for turning vehicles or turning trams), and the reduction in delay at these intersections would be marginally less than that shown in Table 1. These figures demonstrate that, as a rough rule of thumb, a 10 second reduction in cycle time would result in average pedestrian delays being reduced by 1 second.

Reduced cycle times could also have the effect of reducing the queues of pedestrians waiting on the corners of those intersections where footpath overcrowding is a problem at some times of the day. However, as with average pedestrian delay, these benefits would be marginal. A more effective approach would be to widen crosswalks and relocate street furniture.

Lower cycle times mean that the Walk time is shorter each cycle but there are more cycles per hour. Shorter Walk times would result in more occasions, although rare, when slow moving pedestrians have insufficient time to cross the road. This is discussed in a report to Council Planning Committee (City of Melbourne, 2008). The standard design allows for the 85th percentile walking speed of 1.2 m/s. So, about 15% of people walk slower than this. At a cycle time of 70 seconds, a slow walking pedestrian walking at 0.8 m/s would just have sufficient time to cross the road before conflicting traffic starts up, assuming they were to start crossing just 5 seconds into the Walk interval. This is not a major issue across the whole population of pedestrians, but clearly the shorter the cycle time, the more disadvantage there will be for very slow walkers.

Almost all traffic signal sites within the CBD are coordinated with other signals. This is important to maintain smooth traffic flows and minimise the chances of intersections and pedestrian crossings being blocked by queued traffic. Therefore, where reductions in cycle time are proposed, they should be applied to the whole group of coordinated signal sites.

Reducing cycle times will also have an effect on the vehicular traffic, including trams. In times of light traffic, a reduced cycle time will generally reduce vehicle delays. However, if the intersection is close to capacity, a reduced cycle time could increase delays by minutes, rather than seconds, and queues would form between intersections leading to blockages and potential gridlock.

Because trams are generally separated within the CBD, reduced cycle times will generally reduce tram delays. A reduction in cycle time of 10 seconds would reduce average tram delays by about 1.2 seconds, provided no additional traffic blockages were formed.

Active signal priority for trams through 'window stretching' has not been implemented in the CBD. This is because such measures would add to pedestrian delays. To achieve window stretching, either the cycle time must be made longer or the Walk times must be reduced. Furthermore, due to the frequency of tram arrivals in the CBD, window stretching for one tram may adversely affect another tram.

The main constraint on reducing cycle times across the CBD would be those few intersections that have complex phasing and/or wide crossings, such as most of the intersections along Flinders St. The intersections which have simple two-phase operation should be able to operate at lower cycle times without constraint. The question then arises as to which intersections should remain coordinated together operating at the same cycle time. A review of the signal coordination strategy in the CBD could be a worthwhile action in conjunction with VicRoads.

Another area of potential benefit to pedestrians in off-peak conditions would be to refine the SCATS data which governs the cycle time control in SCATS. The cycle time is dependent on the highest degree of saturation measured at any 'strategic approach' in the marriage chain. During heavy traffic conditions, the cycle time is always going to push to the maximum allowable. In off-peak times, when traffic is moderate overall, cycle by cycle variability tends to result in one strategic approach somewhere in the marriage chain having a high degree of saturation each cycle, keeping the cycle time high. This is particularly so in the CBD where marriage chains consist of many intersections. The largest marriage chain in the CBD can consist of 53 intersections and 62 'strategic approaches' pushing for cycle time. Reducing the number of 'strategic approaches' controlling cycle time could reduce delays in off-peak conditions.

Phase splits

Changing phase splits can reduce overall pedestrian delays by favouring the phase which services more pedestrians at the expense of the phase which services less pedestrians. Some pedestrians will wait longer and some will have reduced delay but, overall, delays are reduced. Changing phase splits will also have an effect on the vehicular traffic, including trams.

Walk duration

The Walk time at each crossing is governed by a preset minimum value and the method used to terminate the Walk time in SCATS. The minimum Walk time is generally 7 seconds across the CBD. There are three basic methods for terminating the Walk in SCATS:

- Walk-for-green: the Walk will go as long as possible within the allocated phase time. The Walk terminates the clearance time before the end of the phase so that the flashing red man display finishes at the same time as the lights turn yellow for vehicles.
- Set number of seconds from the end of the phase. For example, if the clearance is 15 seconds, the Walk might be terminated 19 seconds before the end of the phase (subject to the minimum Walk), leaving 4 seconds of steady red man before the lights turn yellow for the vehicles.
- Set number of seconds from the start of the phase. For example, the Walk may be set to terminate at 16 seconds from the start of the phase, provided there is enough time in the phase to accommodate a Walk that long. At short cycle times, the Walk may run for less than 16 seconds but it will never violate the minimum Walk time.

Within the Hoddle Grid (excluding intersections along Victoria St and the 'Little' Streets), there are approximately 212 crosswalks at intersections, controlled as follows:

- 32% Walk-for-green
- 40% seconds from end of phase

- 28% seconds from start of phase

The 'walk-for-green' arrangement provides the longest Walk time and therefore the lowest pedestrian delay. There is potential to review the other 68% of crossings to see if the Walk can run longer within the allocated phase time. There will be some intersections where the Walk time is deliberately set to run shorter to avoid generating queues of left turners who have difficulty filtering through the pedestrian movement at busy CBD intersections. VicRoads has expressed some concern over this effect on left turn traffic, particularly in the CBD. At some intersections, a shorter Walk may be justified to allow the flexibility of phase gapping or to minimise conflict with filtering right turn vehicles. Thus, a universal approach is not warranted. Each site will need to be considered taking these effects into account.

A review of all SCATS pedestrian control data for CBD intersections would be a low-cost initiative with the potential to reduce average pedestrian delays by small but significant amounts. Extending the Walk by 4 seconds, while keeping all other signal timing parameters unchanged, would reduce average pedestrian delay by 3 seconds. There is probably more potential for improvements in pedestrian service through this type of review than through seeking cycle time reductions.

SmartRoads

The SmartRoads framework provides a means of determining the relative roles of different modes of transport in an area, along a route or at an individual intersection. There are always competing demands and Network Operating Plans attempt to set priorities to ensure each part of the road network serves its best role in serving the transport needs of the community. The SmartRoads approach codifies a shift away from the car-centric way of thinking that prevailed some decades ago. SmartRoads recognises the increasing role that buses, trams, bicycles, pedestrians and trucks play in moving people and goods around the network.

Within the CBD and many other parts of the City of Melbourne, the network operating plans would suggest that pedestrians and trams should be "strongly encouraged". The SmartRoads tools provide a means of prioritisation but do not generally have enough detail to determine an appropriate trade-off between small savings in pedestrian and tram delays on the one hand, and traffic queues on the other hand.

Pedestrian safety

An Austroads Internal Report (Austroads, 2001) studied four suburban intersections and concluded that: "Although the results were not significant at all sites, the consistency of results across sites lends some support to the tentative conclusion that reducing signal cycle lengths led to a reduction in the proportion of pedestrians who chose to cross at high risk times in the cycle." High risk times were defined as when the pedestrian crossed while a green or yellow signal was showing for through or turning traffic that conflict with the crossing.

On the other hand, a study at nine mid-block crossings within activity districts (Sinclair Knight Merz, 2007) concluded that: "Simply reducing the maximum time of wait is unlikely to increase compliance rates significantly. Those who wait the longest times are the most likely to keep waiting until a green signal appears." Not surprisingly, the longer a person was observed to wait, the greater were the feelings of impatience. However, pedestrians' feelings of impatience were much higher if they could see no reason for the delay – ie there were no vehicles approaching the crossing. Pedestrians were observed to cross against the red man in the first available gap or wait until the green man appeared. The study suggests that pedestrians cross against the red man "because they can", rather than because they feel impatient with the wait time.

Due to the lack of convincing research either way, it is suggested that the Walking Plan make no claims about reducing pedestrian delays being of benefit to pedestrian safety.

Conclusions

Reducing pedestrian delays is a key action in the Walking Plan. This may be achieved through reduced cycle times, changing phase splits where pedestrian numbers are very unbalanced, or increasing Walk times within the allocated phase time.

Within the CBD, there may be some opportunities to reduce cycle times, particularly in off-peak periods. This would result in very small reductions in average pedestrian delays. Although pedestrian priority may be a key objective within the Network Operating Plan, the small benefits to pedestrians would need to be balanced against the effects on trams and other traffic. Care needs to be taken that changes in signal timings or signal coordination do not exacerbate traffic queues blocking upstream intersections, as this causes delay and frustration to all road users.

A review of SCATS data for cycle time control may achieve slightly lower cycle times in light to medium traffic conditions.

A review of SCATS data for the control of the Walk duration has potential to reduce pedestrian delays. The improvements to pedestrian service would be small but could be achieved across the Hoddle Grid for minimal cost and with negligible disbenefit to other road users. The effect on left turning traffic is the main consideration.

Referencing the SmartRoads approach within the wording of the action is worthwhile as this seems to be the tool that helps to influence signal operations decisions. As there is potential to improve pedestrian service through SCATS data changes to influence cycle times, phase times and Walk times, this is a worthwhile action. This could be done outside the CBD as well, but a realistic target for the duration of this Walking Plan is to address the CBD first.

Recommended Action 1.2.1

Use SmartRoads tools to assess pedestrian delay at intersections across the city and review SCATS data within the CBD to reduce pedestrian delay where practicable.

4. Automatic introduction of pedestrian green 'Walk' displays

The description of this action needs to acknowledge that auto-introduction of Walks is already used throughout the CBD area. Generally, automatic introduction currently applies from 5:30 am to 12:30 am every day, matching the times that tram services are operating. It also applies at all times (24/7) for the crossings of the narrow 'Little' streets (where pedestrian lanterns exist) and at the intersections along King St (Flinders Lane to Latrobe St) and along Collins St (Queen St to Exhibition St).

Auto-introduction is a very sensible mode of operation at intersections where the cycle time is high enough to accommodate the pedestrian movements in their respective phases and pedestrian demand is high. This action addresses the main criticism and frustration that pedestrian express when they miss out on the opportunity to cross the road legally because they pushed the button just after the point at which the Walk demand is registered for the upcoming phase.

While this action is supported generally, there are some drawbacks and exceptions that need to be considered:

- Late night operation
- Conditioning pedestrian to expect the Walk to always introduce
- Exceptions at some wide intersections
- Exceptions at pedestrian operated signals

What should happen late at night when pedestrian demands are low? If all pedestrian movements are introduced automatically, the minimum cycle time needs to allow sufficient time for each phase to service the Walk and Clearance intervals. This could mean that the operating cycle time at night needs to be set at 60 seconds, for example, whereas it could be as low as 40 or 50 seconds if auto-introduction were not implemented.

Almost all pedestrian signals have audio-tactile push buttons. These tick quickly when the display is green walk and slowly the rest of the cycle. The quick ticking can be a nuisance to residents late at night.

The second potential drawback is that a more widespread use of auto-introduction could condition pedestrians to think that they don't need to push the button at night or at intersections further away from the CBD. This concern is dismissed on the basis that all intersections in the CBD and a reasonable number in the greater Melbourne area already operate this way.

When automatic introduction is activated, the red 'wait' light on the push button assembly is illuminated at all times that the pedestrian signals are not showing a green man (see Figure 1). This is a helpful indicator that the pedestrian does not need to push the button as a 'call' is already recorded. In bright sunlight, it can be difficult to see whether the wait light is illuminated or not. In a quick survey of sites in the CBD, it looks like not all push buttons have the 'wait' light. At William St/Bourke St, for example, only 1 of the 8 push button assemblies includes a 'wait' light.



Figure 1 – Push buttons with and without wait lights

There are a few signal sites outside the CBD where auto-introduction would be an overall disadvantage to road users. Pedestrian movements that cross a wide road or boulevard that also carries trams would delay the trams and main road traffic unnecessarily during cycles in which the pedestrian movement runs but no pedestrians are present. Examples are:

- Racecourse Rd / Stubbs St
- Wellington St / Clarendon St
- St Kilda Rd / Commercial Rd

At these types of intersections, auto-introduction would reduce the opportunities to provide signal priority for trams. Signal priority stretches the green window available for trams by shortening the time for side road phases when a tram is present. If a pedestrian movement is running in the side road phase, there is less opportunity to shorten its duration. It is generally advantageous to auto-introduce the pedestrian movements that run parallel with the major road but not those that cross the major road. Although there is some inconsistency in practice here, it is still recommended as the preferred approach.

At pedestrian operated signals, drivers become restless if they have to stop at the signals when there are no pedestrians crossing. Such operation would also reduce the credibility of red traffic signals. It is therefore considered that auto-introduction should not be implemented at pedestrian operated signals. Examples are:

- Bourke St near Hardware Lane

- City Rd near Fanning St
- St Kilda Rd near Bowen Lane
- St Kilda Rd near Coventry St
- Flemington Rd near Melrose St
- Royal Pde near Morrah St (operating isolated)

Auto-introduction can be invoked in various ways. It can be invoked by time-of-day and day-of-week. This makes it completely predictable (for those who happen to know the times) but unresponsive to changing traffic conditions and signal timing requirements. It can be invoked when the operating cycle time is above a certain threshold. This is less predictable but more responsive to irregular changes in demand, such as public holidays, school holidays, seasonal changes and special events. It is recommended that automatic introduction outside the CBD be implemented according to the prevailing phase time or cycle time. A different cycle time threshold may be chosen for the different crossings at an intersection. This allows Walks to introduce automatically when the phase times are sufficient to accommodate the pedestrian Walk and Clearance times, while still allowing the cycle time to drop to lower values late at night when traffic and pedestrian demand is low.

For Walks across very narrow roadways, such as the 'Little' streets in the CBD, automatic introduction would be applied at all times of the day and night.

Along the main boulevards, such as St Kilda Rd, Flemington Rd, Wellington Pde and Victoria Pde, automatic introduction could be applied to the pedestrians running parallel with the main road but it is unlikely to be efficient to do the same for the pedestrians crossing the main road.

These considerations are tactical rather than strategic matters and the Walking Plan does not need to address them in detail but needs to allow the flexibility for them to be played out in the implementation.

Recommended Action 1.2.2

Expand the implementation of auto-introduction of Walk signals at intersections in the area shown in Figure X, where compatible with prevailing signal timings.

5. Pedestrian early starts

This draft action proposes to provide an early start for the pedestrian Walk signal ahead of the parallel vehicle green at signalised intersections. This allows pedestrians to establish themselves on the crossing before left turning traffic has a chance to reach the point of conflict with the pedestrians. The early start is generally in the order of 2 seconds. This type of operation is also called Leading Pedestrian Interval (LPI) in New York.

This measure provides pedestrians with no improvement to their level of service, as the timing of the lights for pedestrians remains unchanged. However, it provides a perceived priority because the parallel vehicle movement is delayed. This can easily be perceived to be an unnecessary penalty for motorists – it is actually achieved through a 'late start' for the vehicle green. Unless there is clear evidence of a safety benefit, it could be difficult to get community support.

A trial would probably need several years of operation before a reliable road safety evaluation would be possible, as the road safety benefits, if any, would be marginal.

A simple implementation of pedestrian early starts would adversely affect trams, buses and bicycles, as they are usually governed by the same green light as the general vehicular traffic. To overcome this, additional lanterns would have to be installed for the relevant vehicle types. An example is shown in Figure 2. This would add a level of complexity, expense and visual clutter that is unlikely to justify the small benefits of a 2 second head start.



Figure 2 – Typical signal lantern arrangement to give early start to pedestrians, bicycles and trams (Bridge Rd/ Church St, Richmond)

General vehicular traffic would be adversely affected by about one vehicle per lane per cycle. In congested conditions, this increases the likelihood of queues banking back to block an upstream intersection or crossing.

The main idea of pedestrian early starts is to overcome the situation where a left turn driver makes their manoeuvre without looking for pedestrians. The delay for the vehicle drivers should get the pedestrian on to the crossing where the left turn driver will see them. However, the benefit of this at intersections along Collins Street, for example, is questionable as drivers would have every expectation that they must give way to pedestrians and driver compliance is good in Melbourne compared to many other cities. The pedestrian early start concept is more likely to have safety benefits where pedestrian presence is unexpected. That is certainly not the case along Collins Street.

When there are many pedestrians waiting to cross, there is always someone who starts to Walk quickly when the green man is displayed. At most CBD intersections in most cycles, the pedestrians are well established on the crosswalk before the first left turn vehicle has a chance to reach the crosswalk. This is even more so as more stop lines are being set back through the installation of bicycle head start boxes and wider crosswalks.

The effect of pedestrian early starts (vehicle late starts) on the operation and safety of hook turns would need to be examined carefully. According to Road Rule 34, a driver undertaking a hook turn needs to wait to complete the turn “until the traffic lights on the road that the driver is entering change to green”. However, many drivers would complete the turn from the propped position within the intersection as soon as the lights facing them turn to yellow. This disparity between expected behaviour and the legal requirements could cause legal problems if any cases went to court. The extra all-red time between vehicle movements is likely to encourage more drivers per cycle to try to complete a hook turn, running the risk of interlocking hook turners. VicRoads has expressed the view (in an email dated 24 March 2014) that “pedestrian early starts cannot be implemented at sites with hook turns”.

Although pedestrian early starts provide a symbolic action showing priority for pedestrians over vehicles, the implementation is not supported for the following reasons:

- They provide no reduction in pedestrian delay
- They adversely impact vehicular traffic

- There is no evidence of a safety advantage. Any such benefit is likely to be small in locations where turning drivers expect to have to give way to pedestrians
- To alleviate extra delays to bicycles, trams and buses, additional lanterns would have to be installed at considerable cost, adding to visual clutter
- They would create legal and operational problems at intersections with hook turns.

It is suggested that pedestrian early starts should be implemented only where it is a technique to overcome a particular problem of conflict between turning vehicles and pedestrians – for example, where there are two lanes of left turning traffic filtering through a pedestrian movement. Widespread implementation is unlikely to be cost effective. If trials are desired to evaluate the safety effects, sites with low pedestrian volumes should be chosen outside the CBD area.

Recommended Action 1.2.3

Delete this action.

6. Pedestrian countdown timer displays

There are two types of pedestrian countdown displays:

- pedestrian clearance countdown, and
- pedestrian wait time countdown.

Clearance countdown

A clearance countdown shows the remaining clearance time during the flashing red man interval. It assists pedestrians in judging the remaining time to complete their crossing of the road.

A few of these countdown displays have been implemented in suburban Melbourne and in other capital cities in Australia.

The countdown can be displayed instead of a flashing red, as shown in the sequence of photos in Figure 3, or it could be a separate display mounted above or beside the red man display, as shown in Figures 4, 5, 6 and 7.



Figure 3 – Integrated clearance countdown display - Adelaide



Figure 4 – Separate clearance countdown display - Brisbane



Figure 5 – Separate clearance countdown display - Sydney



Figure 6 – Separate clearance countdown display – Kew Junction, Melbourne



Figure 7 – Separate clearance countdown display – Bridge Rd/Church St, Melbourne

The Australian Standard AS 1742.14 – Traffic signals does not stipulate the colour or format of countdown timers. However, the current draft which is out for public comment requires the countdown numerals to be yellow, replacing the flashing red man display, as shown in Figure 3.

Replacing the flashing red man display with a countdown timer during the clearance interval will make it difficult for police to enforce the pedestrian lights. Road Rule 231 prohibits a pedestrian starting to cross against a red pedestrian light (whether flashing or not). If there is no red man, then the police cannot enforce during the clearance interval. This may eventually be resolved by an amendment to the Road Rules.

Studies in Australia and New Zealand have not produced any consistent findings in relation to pedestrian behaviour when clearance countdown displays are used. A trial in the Sydney CBD (Levasseur & Brisbane, 2011) found an increase of nearly 12% in the proportion of pedestrians that started late – ie during the flashing red man period. There was no significant change in the proportion of pedestrians who finished late – ie after the start of the conflicting green.

A New Zealand study (Wanty & Wilkie, 2010) found an increase of 20% to 23% in the number of pedestrians that started late and an increase of 11% to 17% in the number of pedestrians who finished late.

A study by ARRB (Cairney, Peter; et al, 2010) for VicRoads reported on a trial of clearance countdown timers at three crossings in Melbourne: Camberwell Junction, Moonee Ponds Junction and Bridge Rd/Church St in Richmond. Less than half the respondents reported noticing the countdown displays. The report concluded that there were “no reliable indications of an improvement in pedestrian behaviour or a reduction in risk to pedestrians”. The results were mixed, and varied from crossing to crossing.

The studies have not been able to show any improvement in pedestrian safety.

There is a growing use of microwave sensors to detect pedestrians still on the crossing. Almost all new pedestrian operated signals installed by VicRoads have this technology. These are termed PUFFIN crossings. One example is in Bourke St near Hardware Lane as seen in Figure 8. An early experiment with pedestrian sensors was carried out in 1996-97 (Catchpole, 1997). Some sensors have also been installed at intersection traffic signals. The sensors are used to vary the pedestrian clearance time, making it shorter than normal if pedestrians clear quickly and longer than normal if there are still slow moving pedestrians on the crossing. This means that the clearance time is not predictable and therefore clearance countdown timers would be inaccurate.



Figure 8 – PUFFIN crossing in Bourke St near Hardware Lane

Widespread implementation of clearance countdown displays is not recommended for the following reasons:

- there is a considerable cost of installation
- there are no demonstrated safety benefits
- they encourage more pedestrians to start to cross illegally after the Walk display has finished
- they are not compatible with the use of pedestrian sensors.

Implementation at a small number of selected locations may be worthwhile as a symbolic treatment to assist pedestrians judging the remaining clearance at locations with wide crossings. A good candidate would be the intersection of Flinders St and Elizabeth St, which has an exclusive pedestrian phase allowing diagonal crossings. This could also be used for further study on the effects on pedestrian behaviour, compliance and safety.

Wait time countdown

A wait time countdown shows the remaining time before the Walk display will come up. It would start timing at the point when the flashing red man changes to a steady red man. The same display can be used to show the remaining Walk time, as shown in the series of photos in Figure 9 from Bogor, Indonesia. In this arrangement, it is inadvisable to countdown the remaining wait time during the clearance interval as pedestrians may misinterpret this to be the remaining clearance time instead of the remaining wait time.



Figure 9 – Wait and Walk countdown display in Indonesia

Wait time countdown displays are practical in some countries which have very simple fixed time traffic signals control systems. However, they are impractical in Australia where signals are controlled by SCATS. There is too much variation in the wait time as SCATS adaptively adjusts the key timing parameters: cycle time, phase splits and offsets. In addition, there are tactical variations due to phases gapping out early, right turn phases being skipped and the actions of window stretching due to active signal priority for trams, buses or emergency vehicles. The intersection signals in the Melbourne CBD with two phases are probably some of the most stable and predictable in Victoria but, even so, errors of up to 5 seconds could be expected.

The draft Walking Plan suggests that technology could be developed to predict the wait time. Such software would need to be very sophisticated to minimise the inaccuracies but, even then, there would be occasions when SCATS second-by-second decisions cannot be predicted.

The effect of wait countdown displays on pedestrian behaviour would need to be carefully examined. There is a danger that more pedestrians would anticipate the onset of the green man and step onto the road when there are 1 or 2 seconds of wait time left. The experience of the Marshalite clocks several decades ago was that drivers tend to pre-empt the signals when they can see the gradual progression towards a green. It is likely that pedestrians would do the same. It is also likely that more pedestrians would try to cross illegally if they see the wait time is very long.

A possible way of mitigating the two problems mentioned above –pedestrians pre-empting the green man and the inaccuracy of the timer – might be to blank the timer when it gets down to, say, 10 seconds. However, this would detract from the function of the timer. It could lead to complaints that the timer is not working properly.

It would be confusing for pedestrians to encounter both wait time and clearance time countdown timers operating in the one city. A consistent approach is preferred.

It is recommended that wait time countdown timers should not be used in Victoria.

Recommended Action 1.2.4

Implement a clearance countdown display at the intersection of Flinders St and Elizabeth St and evaluate its performance.

7. Pedestrian lanterns at all CBD signalised intersections

This proposal involves installing pedestrian lanterns and audio devices at those signalised intersections that currently do not have them.

This would make the crossings more convenient for people with a visual disability and may assist people who can only walk very slowly. It would allow the introduction of audio devices. Push buttons are unnecessary as the Walk would be automatically introduced at all times of the day or night (see section 4 above). However, the audio device without the pushbutton would assist people with a visual disability and may also improve compliance by pedestrians generally.

The width of the 'Little' streets at these intersections is generally about 7 metres and it takes able-bodied pedestrians about 4.5 seconds to cross the roadway. For most of these crosswalks, the clearance time would be set to 6 seconds. Pedestrians who start crossing just as the vehicle lights turn yellow have enough time to clear the crossing during the intergreen – ie before the conflicting green is displayed. Introducing a flashing red man period would add extra delay for those pedestrians who comply, and would lead to a greater level of non-compliance as many pedestrians will cross anyway after checking for traffic, as they do now.

As these streets are one-way, pedestrians crossing on the side where the side road traffic enters the intersection have no conflict with turning vehicles. This crossing is very safe as pedestrians need only look in one direction towards the approaching traffic to judge whether it is safe to cross or not.

The proposal would be reasonably costly. As well as the cost of installing the lantern hardware, each traffic signal controller would have to be reprogrammed. There may be some sites where additional cables need to be pulled through conduits under the intersection. Space would need to be found for the additional hardware. In some cases, additional poles may be required as the existing poles are not in a good position for pedestrian lanterns.

One of the main advantages of the proposal is simply to achieve a consistent treatment across all types of intersections. Some of the 'Little' streets have pedestrian lanterns already. Outside of the CBD, pedestrian lanterns are installed at all crossings, even if the crossing is only across one or two lanes. Across Victoria, these 'Little' street intersections are the only ones that operate without pedestrian lanterns, apart from a few sites where pedestrian numbers are negligible.

Where there are no pedestrian lanterns, pedestrians need to be able to see the vehicle lanterns to judge whether they are permitted to cross. In some cases, the visibility of those lanterns is very limited. In the absence of visible lanterns, pedestrians have to rely on checking for traffic. While this is fairly easy on the approach side of the one-way 'Little' streets, it is not so easy on the departure side. Some pedestrians are observed to simply follow others rather than looking for traffic themselves. At Elizabeth St/Little Lonsdale St on the east side, the vehicle lantern is quite visible when walking south but virtually invisible when walking north, as can be seen in Figure 10.



Figure 10: Visibility of vehicle lanterns at Elizabeth St/Little Lonsdale St

In summary, the advantages of installing pedestrian lanterns at the few remaining intersections without them are:

- Consistency
- Provision of audio devices to assist people with a visual disability
- Slight advantage for people who can only walk very slowly
- Overcoming the existing problem that the vehicle lanterns are not readily visible to pedestrians at some locations
- Some improvement in compliance when the conflicting vehicles have a green light

The disadvantages are:

- Cost of installation and programming
- Visual clutter and extra poles for the additional hardware
- Noise from audio devices
- Longer delays for pedestrians who comply with the flashing red man
- Lack of compliance during the flashing red man period

All in all, it is considered that the benefits outweigh the disadvantages. Uniform application of pedestrian lanterns meets the pedestrians' expectations across the network. Road authorities have an obligation to provide facilities to make it easier for people with a disability to cross the road. The green man display would be introduced automatically at all times of the day and night and would run as 'walk-for-green' – ie the Walk time would equal the phase green time less the short flashing red man time.

Recommended Action 1.2.5

Work with VicRoads to install pedestrian lanterns and audio devices at those CBD crossings that do not already have them.

8. Speed limits and signal operations

The speed limits in the CBD area are shown in Appendix A. They are generally 40 km/h in the Hoddle grid. Outside the CBD, speed limits are generally 60 km/h on arterial roads and 50 km/h on municipal roads.

The intergreen times within the CBD have been adjusted since the speed limit was reduced to 40 km/h.

Apart from the road safety benefits, the effect of reduced speed limits on traffic signal operations would be:

- Potential decrease in yellow times
- Potential increase in all-red times
- Potential change to coordination offsets

Yellow times

According to Austroads Guide to Traffic Management and VicRoads practice, yellow times are calculated according to the assumed approach speed, which is taken to be the speed limit, as shown in Table 2:

Table 2: Yellow times

Speed limit	Calculated Yellow time	Adopted Yellow time
60 km/h	3.78 s	4.0 s
50 km/h	3.31 s	3.5 s
40 km/h	2.85 s	3.0 s
30 km/h	2.39 s	3.0 s

The minimum yellow time is always 3.0 seconds, so the adopted yellow time in 30 km/h zones would be 3.0 seconds rather than 2.5 seconds.

Thus, reducing the speed limit from 60 to 50 or from 50 to 40 would reduce the yellow time by half a second.

All-red times

The period of all-red between consecutive phases is calculated as the clearance distance divided by the assumed clearance speed, which is taken to be the speed limit. The clearance distance is measured from the stop line to the furthest pedestrian crosswalk line. A reduction in speed limit therefore increases the all-red time as it takes longer for vehicles to clear the whole intersection. Typical values are shown in Table 3.

Table 3: All-red times

Case	Clearance distance	All-red time for 50 km/h	All-red time for 40 km/h	All-red time for 30 km/h
Across minor CBD road	15 m	1.1 s	1.4 s	1.8 s
Across major CBD road	27 m	1.9 s	2.4 s	3.2 s
Across boulevard	62 m	4.5 s	5.6 s	7.4 s

In practice, the actual timings would be rounded to the nearest half a second.

Widening crosswalks, as recommended in section 9 below, would also tend to increase the all-red time.

Total intergreen

At most average intersections, a reduction of 10 km/h in the speed limit would increase the all-red time by about half a second, offsetting the decrease in the yellow time.

However, at wider boulevard-type intersections, the total intergreen time for the movement crossing the boulevard could increase by 1.0 or 1.5 seconds.

Coordination offsets

Traditionally, coordination offsets between successive traffic signals along a road are set up to provide progression for platoons of traffic travelling close to the speed limit. To achieve two-way progression, some compromises need to be made to achieve an optimum solution. Within the CBD, generally the offsets for north-south directions are simultaneous. This is because the spacing is quite short and there are often residual queues to clear before the next platoon arrives. Simultaneous offsets also work well to minimise the chances of intersection blockage because the queue should be moving at the upstream stop line at the time the lights change to yellow. This also minimises the chances of a vehicle being stranded over a crosswalk when the green man comes on.

For these reasons, the north-south offsets would remain as simultaneous offsets regardless of the speed limit. The only effect of reducing the speed limit would be that vehicles would have more stops in light traffic conditions, probably having to stop at every second light instead of every third light as they drive north or south.

For east-west traffic, the arguments are similar but not quite so strong. With intersections spaced at 230 m, the travel time is about 21 seconds at 40 km/h. During heavy traffic periods, the best option is simultaneous offsets with cycle times around 80 to 90 seconds. In very light traffic conditions, alternate offsets would work better at a cycle time of around 50 seconds. This would also discourage speeding. The effects on stops and delays for trams would need further investigation.

Adjusting offsets due to the change in speed limit is unlikely to have much effect on pedestrian service.

9. Other potential actions to improve pedestrian service

Strategic actions to improve pedestrian service need to be targeted to the main frustrations that pedestrians experience. Some of the frustrations are:

- Crowding on corners making it difficult for pedestrians heading for one crossing to get through the crowd waiting for the perpendicular crossing
- Vehicles blocking a crossing because of queuing along a road - this seems to happen more for eastbound traffic in the afternoons
- Weather: getting wet; having to put ones' umbrella up and down where awnings are not consistent along a footpath; waiting in the cold, waiting in the heat.

Other potential actions for the Walking Plan are discussed below.

Widen crosswalks at busy crossings

The standard width of crosswalks at signalised intersections is 2.4 m. However, they can be widened up to 5.0 m at busy crossings (see Traffic Engineering Manual volume 2, section 17.3). In the CBD, most older crosswalks in the central area are about 3 m wide.

At some intersections where new tram stops have been constructed, crosswalks have been made very wide to cater for groups of pedestrians alighting from trams, as can be seen in Figure 11. At other intersections, the crosswalk is still quite narrow, even where there is a tram safety zone, as seen in Figure 12.



Figure 11: Wide crosswalk at Elizabeth St/Little Bourke St



Figure 12: Narrow crosswalk at William St/Bourke St

Wider crosswalks can reduce the problem of pedestrian crowding on footpath corners. They also minimise the conflict between opposing pedestrians as they cross the road.

The main disadvantage of wider crosswalks is that the all-red time increases which adds to the lost time to the detriment of green time for all road users. The amount of vehicle storage space is reduced, resulting in longer vehicle queue lengths. Signal posts will often need to be relocated adjacent to the new stop line. These effects are worse if bicycle head-start boxes are also installed.

As a rough guide, crosswalks could be made 4 m wide as a general rule across the CBD and 8 m wide where the crosswalk feeds a tram stop or where pedestrian crowding is a problem.

To provide for future increases in pedestrian numbers, it is worthwhile implementing wider crosswalks whenever opportunities arise with installation of new tram stops, geometric works and when road resurfacing is carried out.

Recommended action:

Widen crosswalks within the CBD that are less than 4 m wide.

Build kerb outstands

By building out kerbs, intersections can be made narrower. This shortens the length of the crosswalk and consequently the pedestrian clearance time can be reduced. In addition, the all-red time might be reduced marginally. The time saved can be given back to the pedestrians as extra Walk time or can be used in light traffic conditions to reduce the cycle time.

Additional footpath space is more comfortable for waiting pedestrians and will help to reduce crowding at busy intersections.

An example of a kerb outstand is at Russell St/Bourke St on the NW corner, as seen in Figure 13. There are many places where kerb outstands could be constructed around the CBD. Two examples are shown in Figures 14 and 15.



Figure 13: Kerb outstand at Russell St/Bourke St, NW corner



Figure 14: Potential for kerb outstand at Russell St/Bourke St, SE corner



Figure 15: Potential for kerb outstands at William St/Little Collins St, west side

Recommended action:

Build kerb outstands at CBD intersections where there is space to do so.

Relocate footpath furniture away from corners

Where pedestrian crowding is a problem, or could become a problem in the future, the area of the footpath near the crosswalk should be kept as clear as possible. This is important so that pedestrians with a visual disability do not walk into furniture. It also provides more space to avoid crowding. The clear area should be the extension of the crosswalk lines, not just the area adjacent to the kerb ramp.

Road furniture includes power poles, signal poles, rubbish bins, pedestrian plinth direction signs, poles for parking signs, etc.

Although this is not a problem at the great majority of intersections, there are some locations where improvements could be made. At Elizabeth St/Latrobe St, for example, there are three rubbish bins and two poles in line with the TGSIs leading pedestrians from the tram stop to the footpath (see Figure 16).



Figure 16: Footpath furniture in line of the crosswalk at Elizabeth St/Latrobe St, SW corner

Recommended action:

Relocate footpath furniture away from corners at busy intersections.

Encourage police to enforce vehicles blocking intersections and crossings

There is little that can be done in terms of traffic engineering techniques to minimise drivers blocking intersections or crossings. Placing signs warning drivers to 'Keep Intersection Clear' is not effective and merely adds to sign clutter. The Road Rules are quite clear that drivers must not block intersections or crossings. The best approach is enforcement.

Police enforcement campaigns are generally driven by road safety issues – and rightly so. However, there are many other rules and laws that are a matter of public order, frustration and fairness, rather than safety, which also need enforcement, even if it is only to a low level. The important ingredient is some media coverage so that the driving public understand that there can be consequences if these rules are breached. If there is good media coverage, then the blitz might only need to be over two days per year, say.

Suitable intersections should be found for enforcement. Because of the difficulty in pulling drivers over on the departure side of an intersection, it might not be possible to enforce the locations with the worst problems. That is not critical as the main aim is to send a message to the driving public that blocking intersections is an important issue and that it is being enforced. The

Police should be able to find locations where safe arrangements can be made where parking would normally be allowed or in a side lane just past the intersection. An unmarked Police car could be parked and space reserved to interview offending drivers.

It would be worthwhile seeking statistics on how many infringements have been issued within the City of Melbourne in the last 12 months in relation to Road Rule 128.

Recommended action:

Encourage police to enforce vehicles blocking intersections and crossings.

Other actions

- Continue to improve pedestrian kerb ramps and install and maintain tactile ground surface indicators (TGSIs) at all crossings
- Continue the program to retrofit audio-tactile devices at all traffic signals
- Look for opportunities to install pedestrian zebra crossings at suitable mid-block locations
- Encourage building owners to add awnings over the footpath where there are gaps along major roads in the CBD, such as:
 - Elizabeth St between Bourke St and Lonsdale St, west side
 - 267 to 273 Swanston St, near Lonsdale St corner
 - Maybe modern ones could be retractable

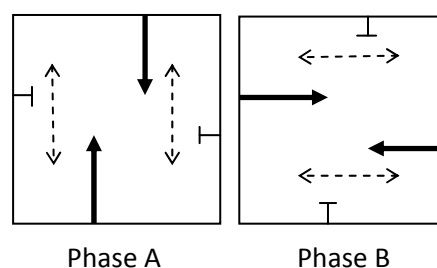
10. Exclusive pedestrian (scramble) phases

Exclusive pedestrian phases are sometimes called a Barnes Dance or a scramble crossing. During this phase in the traffic signal cycle, pedestrians are allowed to walk diagonally across the intersection as well as parallel to the roads. An example is at the intersection of Flinders St and Elizabeth St.

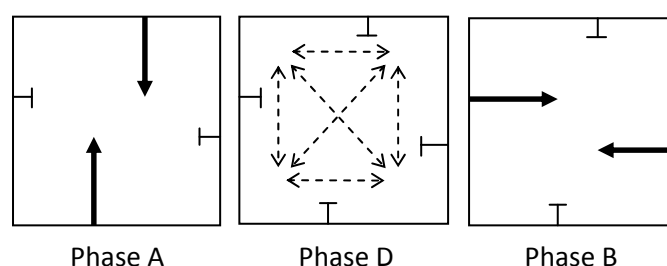
Intuitively, it may seem that providing a scramble phase would improve pedestrian service but this is demonstrably not the case in the great majority of typical intersections. A study of two typical CBD intersections, Collins St/Exhibition St and Spencer St/Little Collins St (Nash & Smith, 2010) (John Piper Traffic Pty Ltd, 2008), found that implementing a scramble phase at each intersection would:

- result in slight increases in overall average pedestrian delay
- markedly increase overall average vehicle delay
- increase average tram delays by at least double.

The phasing arrangement for a typical cross intersection is shown in Figure 17.



(a) Existing



(b) With scramble phase

Figure 17: Phasing arrangement for scramble phase

While the pedestrians get a very good go when the scramble phase runs, they have to wait for the whole of A and B phases while the vehicles get a go. Furthermore, within the scramble phase, the pedestrian clearance time needs to be sufficient for a pedestrian to clear diagonally rather than just straight across the intersection. For a typical CBD intersection, the Clearance interval would increase from about 16 seconds to 26 seconds, which is 10 seconds of additional lost time in the signal cycle.

Running scramble phases would make it more difficult to achieve lower cycle times in light traffic conditions. The absolute minimum cycle time would be 65 s, made up of 15 s for each of A and B phases plus 35 s for the scramble phase, assuming all three phases run each cycle.

The key results are shown below in Tables 4 and 5.

Table 4: Collins Street / Exhibition Street – Scramble Phase

Phasing / Analysis Period	Degree of Saturation	Average Pedestrian Delay (secs)	Average Vehicle Delay (secs)	Average Tram Delay (secs)
Existing – AM Peak	0.59	29.8	26.2	14.9
With scramble – AM Peak	0.75	32.9	36.2	36.5
Increase	0.16 (27%)	3.1 (10%)	10.0 (38%)	21.6 (145%)
Existing – Midday Peak	0.57	30.2	26.6	14.5
With scramble – Midday Peak	0.52	32.9	34.4	33.2
Increase	-0.05 (-9%)	2.7 (9%)	7.8 (29%)	18.7 (129%)
Existing – PM Peak	0.72	29.9	24.9	15.4
With scramble – PM Peak	0.76	32.9	37.2	32.1
Increase	0.04 (6%)	3.0 (10%)	12.3 (49%)	16.7 (108%)

Table 5: Spencer Street / Little Collins Street – Scramble Phase

Phasing / Analysis Period	Degree of Saturation	Average Pedestrian Delay (secs)	Average Vehicle Delay (secs)	Average Tram Delay (secs)
Existing – AM Peak	0.39	44.8	12.4	8.8
With scramble – AM Peak	0.45	47.7	23.3	18.7
Increase	0.06 (15%)	2.9 (6%)	10.9 (88%)	9.9 (113%)
Existing – Midday Peak	0.30	32.7	12.4	10.3
With scramble – Midday Peak	0.43	37.8	26.0	21.8
Increase	0.13 (43%)	5.1 (16%)	13.6 (110%)	11.5 (112%)
Existing – PM Peak	0.50	39.7	13.9	9.2
With scramble – PM Peak	0.44	42.8	27.5	22.4
Increase	-0.06 (-12%)	3.1 (8%)	13.6 (98%)	13.2 (144%)

In a close grid network, the increases in vehicle delays and queuing may have wider effects in the busy times of the day as queues build to adversely affect upstream intersections.

Scramble phases are likely to have safety benefits for pedestrians, as there are no vehicles permitted to proceed during the scramble phase. However, safety outcomes are not always obvious. There is the difficulty of keeping pedestrians on the footpath during the vehicle phases when pedestrians may think they can cross while the parallel vehicles have a green light, particularly if delays are getting longer. These effects would require further studies from a field trial.

Once a scramble phase is introduced, it is very difficult to remove it. Pedestrians get used to certain operations and take time to adjust to different phasing. It is also inadvisable to operate a scramble phase at some times of the day then revert to normal two-phase operation at night. Safety is dependent on operating conditions meeting road users' expectations.

It is recommended that scramble phases should not be considered as part of the Walking Plan.

11. Measures of pedestrian delay

Probably the best indication of pedestrian delay would be to take a large sample of pedestrians, time their delay and average the results. However, this is clearly a time-consuming and expensive task. It also raises the question as to whether small delays experienced by pedestrians who blatantly disregard the traffic signals should be included or not.

The most practical measure for pedestrian delay is the theoretical average delay. This assumes:

- random arrivals
- fixed time signals with automatic introduction of the green man display
- full compliance with the signals
- no queued delay.

The simple formula for average delay is:

$$d = \frac{r^2}{2c}$$

where r = the red time and c = the cycle time

Including queuing, the formula becomes:

$$d = \frac{r^2}{2c(1-y)}$$

where $y = q/s$, q = arrival flow, s = saturation flow

(SIDRA assumes a saturation flow of 12,000 pedestrians per hour)

However, the effect of queuing delay is negligible in most cases. Even with very high pedestrian arrival flows, the effect of queuing delay might add only 1 or 2 seconds to the average delay using the first formula.

Good figures on pedestrian volumes are not available for most intersections.

If the pedestrian Walk is not introduced automatically, then there could be some occasions where the pedestrian arrives during the time the green man would normally be displayed but nobody has pushed the button previously. The theoretical average delay in such cases is $c/2$. Again, in the City of Melbourne where pedestrian volumes are high, this effect is negligible.

At pedestrian operated signals and at some intersections where the pedestrian phase is activated more often by pedestrians rather than vehicles, the point at which the green man is displayed is a window rather than a fixed point in the cycle. This provides more flexibility in serving a pedestrian who pushes the button a few seconds too late, thus reducing the delay marginally.

The other complication is where pedestrians stage their crossing. This occurs at some split pedestrian operated signals and at some intersections with very wide roads, such as St Kilda Rd, Flemington Road and Royal Parade. These sites need to be assessed on a case-by-case basis.

At intersections, the average delay calculated for each crossing should be weighted according to the number of pedestrians using the crossing. The weighted average would then be a measure for overall average pedestrian delay at the intersection. Where pedestrian volumes are available, this would be a worthwhile refinement.

For the purposes of a strategic assessment of pedestrian delay across all signal sites in the City of Melbourne, it is suggested that the most practical measure is the simple delay formula. This should be calculated for each crossing and, if pedestrian volumes are known, weighted according to the number or proportion of pedestrians using each crossing. If pedestrian volumes or proportions are not known, a straight average should be taken.

12. Integrated package of actions

The key actions related to signal operations recommended for the Walking Plan are:

- Use SmartRoads tools to assess pedestrian delay at intersections across the city and review SCATS data within the CBD to reduce pedestrian delay where practicable.
- Expand the implementation of auto-introduction of Walk signals at intersections in the area shown in Figure X, where compatible with prevailing signal timings.

- Implement a clearance countdown display at the intersection of Flinders St and Elizabeth St and evaluate its performance.
- Work with VicRoads to install pedestrian lanterns and audio devices at those CBD crossings that do not already have them.

Other potential actions that could be added to the Walking Plan are:

- Widen crosswalks within the CBD that are less than 4 m wide.
- Build kerb outstands at CBD intersections where there is space to do so.
- Relocate footpath furniture away from corners at busy intersections.
- Encourage police to enforce vehicles blocking intersections and crossings.
- Continue the program to retrofit audio-tactile devices at all traffic signals.

These actions are all compatible. Implementing auto-introduction of Walk signals outside the CBD will address one of the main frustrations that pedestrians encounter. Concentrating the SCATS data review in the CBD will achieve small gains across many intersections where pedestrian volumes are high. Such a review could be expanded to the remainder of the municipality over subsequent years.

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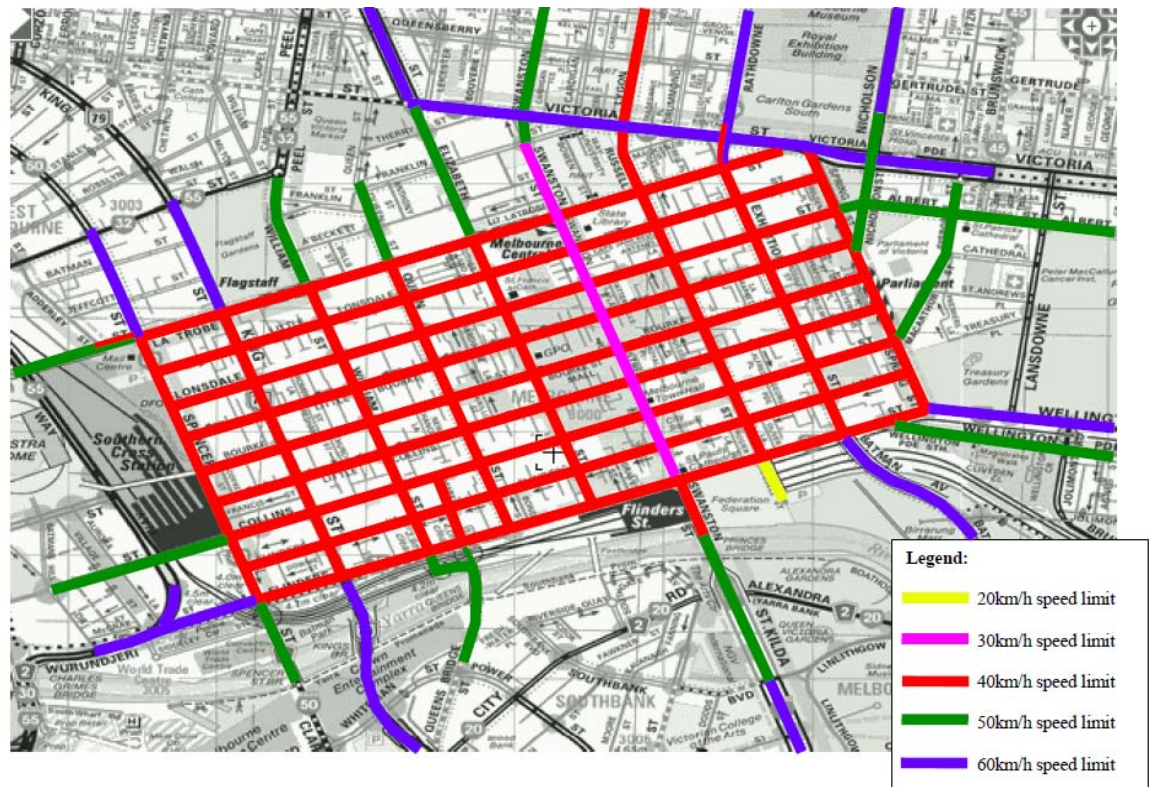
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Acknowledgements

The author acknowledges the kind assistance of the following people:

- Martin Chelini – VicRoads
- Mahes Mahesan – VicRoads

Appendix A – Speed limits in the CBD area



Source: City of Melbourne website

Appendix B – Glossary

The following technical terms have been used in this report:

Clearance time	The duration of the flashing DONT WALK or flashing red man display for pedestrians.
Cycle time	The time to service all phases.
Gapping	When a phase terminates earlier than its nominal end point due the detection of gaps in the traffic streams that the phase services.
Intergreen	The time period between green displays in successive phases, consisting of yellow time and all-red time.
Marriage chain	Intersections are grouped into sub-systems which can be coordinated together, or “married”, forming a chain of married sub-systems. Married sub-systems operate at the same cycle time.
Offsets	The time from when the signals turn green at one signal site until the signals turn green at the next signal site. Offsets can be set to provide traffic with progression along a road, but need to consider both directions of travel. In congested conditions, the offsets can be set to minimise blockages.
Phase	A period of time when a set of traffic movements have a green light, including the intergreen.
Phase splits	The proportion of the cycle time allocated to each phase.
Strategic approach	A set of detectors on one approach which monitor the volume and density of traffic and can be used to control phase splits and cycle time.
Sub-system	One or a group of signal sites (intersections or pedestrian operated signals) which always operate at the same cycle time.
Walk time	The duration of the WALK or green man display for pedestrians.
Window stretching	The technique for starting a phase earlier or extending it later when a priority vehicle (usually a tram or bus) is approaching.

