A SAFE SYSTEM APPROACH TO PEDESTRIAN SAFETY ON WELLINGTON'S CENTRAL CITY BUS CORRIDORS

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Abstract

A pedestrian died after being struck by a bus in broad daylight while jogging across Willis St, one of Wellington's central city bus corridors in June 2011. Six other pedestrians have been hit by buses there since November 2010. Bus priority measures and route changes have been implemented in Wellington to make public transport more attractive in terms of travel time relative to private motor vehicles.

The Golden Mile traverses some of the most intense pedestrian and street activity space in Wellington. The "place" function of the Golden Mile is considered to be more important than the "movement" function and pedestrians have been given higher priority than public transport (while general traffic has been excluded altogether). Accordingly, buses could be considered as "guests" in that space, with traffic speeds expected to be slow (well under 30 km/h) and drivers behaving as though pedestrians are the "owners" of the street.

This technical note is an outside perspective on how such tragedies might be avoided in future. It uses a "safe systems" approach, whereby it is acknowledged that while mistakes by road users are inevitable, systems are needed to protect people from death or serious injury.

Introduction

Vanessa Green died after being struck by a bus while jogging across Willis St (part of the Wellington central city "Golden Mile") on the afternoon of Tuesday 28 June 2011. Six other pedestrians have been hit by buses since November 2010 (Chapman 2011).

This technical note is an outside perspective intended to stimulate discussion about how such tragedies might be prevented in future. The authors visited the site in July 2011 and have reviewed media reports and Wellington City Council (WCC) published documents. WCC commissioned and responded to a detailed formal safety audit (Beca 2011). The role of a safety auditor is to identify and rank all safety concerns, not to propose solutions. This paper takes a higher level view of key issues and suggests a range of possible measures to improve pedestrian safety on Wellington's central city bus corridors.

Bus priority measures and route changes have been implemented to make public transport (PT) more attractive in terms of travel time relative to private motor vehicles. The introduction of buses on Manners Mall, which was previously traffic-free, has been contentious. In this context, crashes receive substantial media coverage and are debated in a politically charged atmosphere, with less objectivity than desirable brought to bear on important transport decision-making.

When changes are made to a transportation system, there is often a settling-in period where users become familiar with the new environment. This can take several months or longer, as users adjust to the changed environment. Although a longer time frame is often preferred for robust before-and-after safety analysis and potential remedial action, the crash record of seven pedestrian crashes (including one fatality) in seven months on Manners Mall / Willis St is likely to drive quicker action. For example, one Wellington city councillor has suggested a trial of a nautical rope barrier along the kerb along the former Manners Mall ('Pedestrian fences proposed for Manners St' 2012).

Figure 1: Pedestrians cross Manners St at will amongst buses

The Safe System Approach

The National Road Safety Committee's *Safer Journeys Action Plan 2011-2012* states:

"The Safe System approach acknowledges that even responsible people sometimes make mistakes when travelling on the roads. This is a change from traditional approaches that tended to blame the road user for causing a crash. Given that mistakes are inevitable, we need the system to protect people from death or serious injury.

To do this the Safe System has objectives to:

- *Make the road transport system more accommodating of human error*
- *Manage the forces that injure people in a crash to a level the human body can tolerate without serious injury*
- *Minimise the level of unsafe road user behaviour"*

These objectives are related to the Safe System elements illustrated in Figure 2.

The elements are interpreted in terms of Wellington's central city in Table 1, where the activity and place function is much different than a Safe System approach for a 100 km/h rural highway.

Figure 2: Safe System elements

Table 1: Safe System approach in the context of this technical note

Safe System elements[1]	Wellington central city context
Safe vehicles with advanced safety features to help prevent crashes and protect road users	Collision avoidance technologies installed on buses are available and may be appropriate.
Safe roads and roadsides that are predictable and forgiving of mistakes – their design should encourage appropriate road user behaviour and safe speeds	Research suggests that the form of the urban environment is likely to have a greater effect than forgiving roads on safety, especially for non motorised road users (Dumbaugh & Li 2011). Road space allocation and design will depend on the definition of 'appropriate' road user behaviour and motor vehicle speeds
Safe speeds that suit the function and level of safety of the road; managed through more appropriate speed limits and self-explaining roads	Speed limits and operating speeds are a major factor in pedestrian safety; the activity and place function and pedestrian safety should inform the appropriate speed
Safe road use ensuring that users are alert and aware of the risks and drive to the conditions	Alert, compliant road users are a critical part of a safe system. All road users (including pedestrians and bus drivers) have responsibilities for the safety of themselves and others.

[1] Adapted from NZTA pamphlet *Introducing the Safe System approach to road safety*

Current Design and Operation

The corridor

The Golden Mile extends from the Lambton Quay bus interchange to the Embassy Theatre end of Courtenay Place. This includes Lambton Quay, Willis Street, Manners Street and Courtenay Place.

In November 2010, the former pedestrian-only Manners Mall was opened for two-way bus traffic. The pedestrian mall was converted to a narrow roadway (6.5 m) and broad footpath configuration. Standard height kerbs, street trees, and benches have been provided consistent with other Wellington central city streetscapes.

A similar change has also been completed recently in the Bankstown, Sydney central city although Bankstown also included concrete barriers between the footpaths and carriageway (Morrison 2009).

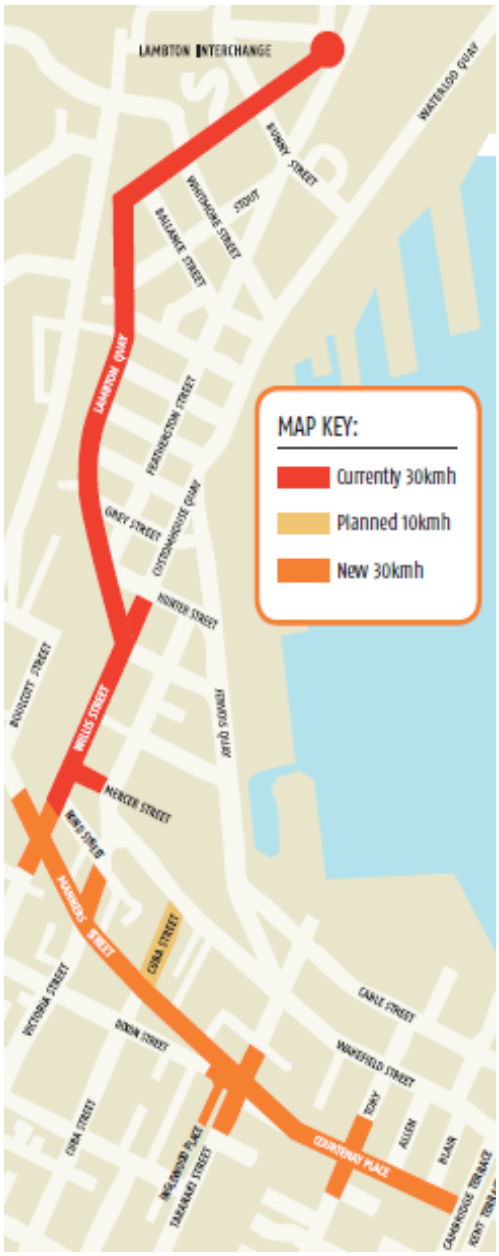


Figure 3: The Golden Mile (WCC 2010)

Speed reduction

The Willis Street speed limit was reduced from 50 km/h to 30 km/h after a pedestrian fatality in 2005. The conversion of Manners Mall to a bus corridor also included a 30 km/h speed limit.

These changes have been accompanied by large pavement markings and electronic speed variable message displays placed at several locations to improve driver awareness of their midblock operating speeds and adherence to the speed limit.

Physical traffic calming measures

On the former Manners Mall, the carriageway width has been minimised to provide more footpath space and create a lower speed environment.

Paving stones are used to provide audio-tactile cues to drivers about the speed environment on Lambton Quay.

Pedestrian education

Education is used on the bus corridor to minimise the risk of pedestrians stepping into the street without looking.

"LOOK RIGHT" kerb markings are provided at close spacing on kerbs and at pedestrian kerb cut-downs (ramps) throughout the central city area. They are especially prevalent where traffic flow directions on one-way streets have reversed or become two-way.

Public service messages encouraging pedestrians to look both ways have been conveyed through the media and are prominently displayed on street signage.

These signs should not obscure intervisibility between pedestrians and buses.

Key Safety and Design Issues

Bus speed

At peak periods, midblock bus speeds appear to be between 10 and 25 km/h. During periods of low pedestrian and bus activity, bus operating speeds are likely to be higher, reducing the ability of drivers to avoid crashes and increasing the severity of crashes which do occur.

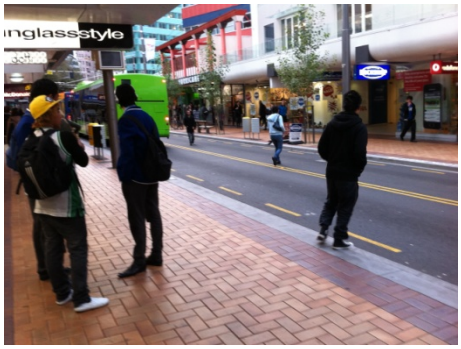
Large kerb radii allow higher motor vehicle cornering speeds and are designed to minimise turning vehicle delay. Opportunities to reduce corner radii could be explored. Designing tighter kerb radii for the "checking vehicle" (i.e. larger vehicles must cross the centreline or use adjacent lanes when turning) rather than the "design vehicle" (i.e. larger vehicles can turn entirely within their lane) is supported in Austroads and the UK's Manual for Streets 2 (Austroads 2009b; Department for Transport 2010).

Corridor width and intervisibility

Many central city commercial streets with high frequency public transport services (e.g. Nicollet Mall, Minneapolis; 16th Street Mall, Denver; Bourke Street, Melbourne) are wider than parts of the Wellington corridor. Insufficient width will result in pedestrians using the carriageway to get around bottlenecks and a consequent increased safety risk.

In a constrained corridor, billboards, phone boxes and other large street furniture positioned close to the road can conceal approaching buses and block drivers' views of pedestrians. In the recent fatal crash, a large sign located about 0.7 m from the kerb edge (and subsequently removed) may have been a contributing factor in the collision.

Pedestrian behaviour



Pedestrians crossing midblock sometimes risk being struck by buses. Pedestrians may legally cross the road midblock if more than 20 m from a controlled crossing. The risk of conflict is higher when crossings are attempted close to an uncontrolled intersection or where sight distance is poor.

Pedestrians may also misjudge gaps between buses or bus approach speeds. Bus drivers were observed to minimise following distance to discourage pedestrians from crossing between buses.

While pedestrians have responsibilities for their own safety, road design and the way traffic operates will also affect safety outcomes.

Possible Measures

The current design and operation of this PT corridor is unusual (with just buses and pedestrians) and because of the recent conversion from a pedestrian-only environment in Manners Mall, pedestrians may not expect to share space with buses. The Safe System approach recognises that people make mistakes and that we should:

- *Make the road transport system more accommodating of human error;*
- *Manage the forces that injure people in a crash to a level the human body can tolerate without serious injury; and*
- *Minimise the level of unsafe road user behaviour.*

The Safe System elements have been used as categories for possible remedial measures. Most options are not mutually exclusive and may fall into more than one category.

Safe speeds

Higher bus speeds increase the likelihood of a crash with a pedestrian and the severity of any crashes. In addition to improving safety, reducing speed will also have benefits in terms of reducing noise, fuel use, vehicle operating costs and road maintenance costs. Operating speeds may be reduced through any combination of PT service changes, lower speed limits, increased enforcement and changes to the street environment.

Any discussion of speed needs to be informed by public transport service considerations. The competitiveness of PT is affected by the total trip time relative to the private car.

The opening of Manners Street to buses has already reduced travel time by improving directness and reducing traffic delay. For a fixed distance, travel time is reduced by maximising speed and minimising delay. Travelling faster may be seen by drivers as necessary to stay on schedule. Conversely, minimising stop delays will reduce the required cruise speed, all else being equal.

What is the desirable operating speed?

No literature was found specifically identifying appropriate speeds for buses in central city or otherwise-pedestrianised streets.

To comply with the regulatory requirement that speed limits be set in multiples of 10, the options are:

- 30 km/h – status quo
- 20 km/h
- 10 km/h – to minimise speed differential with a typical pedestrian speed of 4 km/h

A recent detailed crash study entitled “Designing for the Safety of Pedestrians, Cyclists, and Motorists in Urban Environments” (Dumbaugh & Li 2011) included guidance on what speeds are appropriate to maximise safety, suggesting that 30 km/h is appropriate in central city streets. Research on pedestrian fatality risk (Koorey 2011; Rosén & Sander 2009) is based on all vehicles rather than just heavy vehicles such as buses. As buses are nearly eight times more likely to kill a pedestrian than cars per vehicle kilometre travelled (Paulozzi 2005), a speed limit lower than 30 km/h may be justifiable.

The desirable operating speed may be influenced by timetable requirements. Assuming no stops, Table 2 shows the time required to travel one kilometre at different speeds.

Table 2 Time to travel one kilometre at different speeds (no stops)

km/h	minutes/km
10	6.0
20	3.0
30	2.0
40	1.5
50	1.2
60	1.0

Thus reducing the operating speed from 50 km/h to 30 km/h increases travel time over one kilometre by less than a minute. Reducing operating speeds from 30 km/h to 20 km/h increases travel time by one minute. But these theoretical "costs" of reducing operating speeds would be higher than experienced in practice, as bus stops along the route mean that maximum speeds are severely restrained. Much of the time required for buses to travel through central Wellington is associated with accelerating and decelerating at bus stops and boarding and alighting time.

The desirable operating speed may be achieved by independent options including timetable changes, bus operator regulations, speed limit changes and enforcement, and vehicle speed limiters.

Establishing the desirable operating speed may be informed by considering the numbers of users by mode. In a typical day, how many pedestrians and how many bus passengers use the former Manners St Mall? If the numbers of pedestrians outweighs the numbers of bus patrons, then this would support reducing the speed limit on the street. Conversely, if there were many more bus passengers traversing a particular block of the street, then it might be appropriate to establish a higher operating speed and to prevent pedestrians from entering the bus carriageway on safety grounds. The level of service for pedestrians and bus patrons might reflect their relative importance in the traffic mix.

Managing cruise speed through reduced delay time

The Safe System approach suggests that safe speeds suit the function and level of safety of the road. As the Golden Mile currently has both pedestrian and bus movement functions, determining appropriate operating speeds will depend on pedestrian safety and PT system design considerations.

To reduce the peak speed without affecting total trip time, the delay time could be reduced by measures including:

- Minimising intersection delay through traffic signal priority measures
- Minimising congestion through PT exclusive corridors
- Reducing the number of stops – rather than the commonly applied 200 m, European practice is to space stops every 320 m (Currie & Ceder 2008)
- Locating bus stops downstream of signalised intersections rather than upstream
- Reducing bus stop delay time by adjusting vehicle acceleration and deceleration rates, and kerb design and geometry.
- Reducing time spent at bus stops by improved fare payment systems (either on board or at the kerb), or increasing the number and/or width of doors.

Managing speed through the street environment (engineering)

Possible engineering measures can either reduce the probability of conflicts or the severity of any conflicts which may occur.

- Carriageway width has an influence on driver perception of the speed environment; however on Manners Street this may already be as narrow as practicable with two-way bus traffic.
- Frequent 30 km/h markings and electronic speed display signs are already present. Audio tactile paving may be used, but this may have unacceptable noise implications for adjacent land uses.
- Raised platforms are another physical approach to speed management. Platforms at footpath level may also double as pedestrian courtesy crossing points to focus pedestrian movements into more predictable and concentrated locations. These points may be encouraged through physical measures such as low landscaping or barriers elsewhere along the corridor.

  However, such devices may introduce additional deceleration and acceleration noise, vehicle operating costs, and discomfort for bus occupants. Although these concerns may be addressed through detailed design, such as the Danish "K-Hump" alternative profile (Jarvis 1992), physical measures to manage bus speeds are an expensive option with the potential for strong opposition by bus operators.

Managing speed through GPS units on buses

Buses typically are equipped with global positioning systems (GPS) that allow bus operators to monitor the speeds of buses in their fleets. This capacity could be used by bus companies and / or GWRC to monitor the speeds of individual buses. Bus drivers should be advised that this technology will be used to observe bus speeds in these sensitive locations and to manage driver performance issues as necessary.

Safe Roads

Overall design concept

WCC has to balance the function of each street in the network and has chosen a high priority for public transport on the Golden Mile to reduce travel time. In the long term, it may be that travel patterns and activity locations change sufficiently to enable a vehicle-free Golden Mile, which would be safest for pedestrians.

Barriers

The most often mentioned solution to concerns about pedestrian safety in crowded urban spaces is barriers. In the words of the Dominion Post editorial (5 July 2011):

> *...the area of Willis St where she was hit does not feel like a busy inner-city thoroughfare. It is lined with trees and park benches, creating the impression of a quiet avenue and increasing the risk of someone stepping on to the road without thinking....Barriers are the most effective way to stop people from crossing roads in areas where it is not safe to do so...The flower beds and small wrought-iron fences that deter people from walking on to Bowen St before the controlled crossings at the Lambton Quay end are an example of how a safety feature can also be made attractive. Simply placing planter boxes or knee-high fences along streets where the new bus lanes run could be enough...*

In the United Kingdom, pedestrian barriers are being removed on many high traffic streets (Department for Transport 2010; Hamilton-Baillie 2008). Motorists tend to drive faster when they perceive less probability of conflict, thereby increasing the severity of crashes which do occur.

The redevelopment plan for the London borough of Hounslow identifies the need to remove safety barriers (London Borough of Hounslow & AECOM 2009) and improve pedestrian crossings. The plan declares that pedestrian safety guard railing clutters the streetscape and creates entrapment situations.

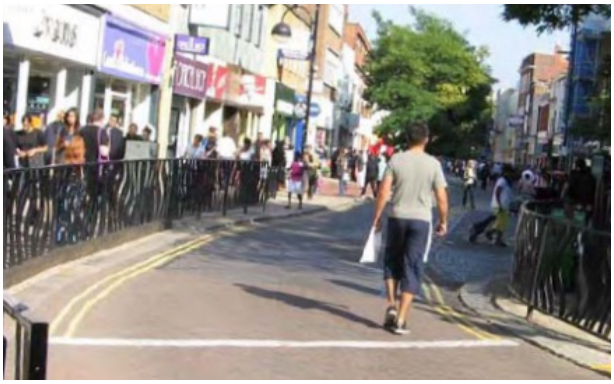


Figure 4: People may walk on the road if frequent barrier gaps are not provided (Hounslow, London)

The potential safety benefits of restricting crossing locations may be offset by increased risk posed by higher vehicle travel speeds, increased pedestrian travel times, and the potential for pedestrian entrapment on the carriageway.

Alternatives to fences include:

- Low barriers comprised of hardy landscaping (traversable by the able bodied) or planter boxes, with frequent gaps for crossing opportunities. This would cater for pedestrian desire lines but discourage crossing at points of poor visibility.
- Nautical rope barriers as suggested by a city councillor ('Pedestrian fences proposed for Manners St' 2012), which (as above) may include frequent gaps where intervisibility is not impeded.

Any barrier should be placed such that pedestrians have enough space between the barrier and the kerb face to avoid vehicles at any point along the carriageway.

Intervisibility

When using intervisibility to determine sight line distances in different operating speeds, the underlying assumption is that the road has priority and drivers will be able to stop within the available sight distance provided. This is not really the case in a shared environment where traffic speeds range from 4 km/h for pedestrians to 30 km/h (or more) for buses. Austroads (2009a) guidance for safe stopping distances is not provided for speeds less than 40 km/h. However, there is an expectation that bus drivers and pedestrians should be able to see each other. It is possible that pedestrians are not expecting buses and vice versa.

Network design

At the strategic level, the PT system itself could be changed to different routes or system types. Routing could be changed to avoid areas of high pedestrian concentration, instead using existing traffic priority corridors with exclusive lanes to minimise general traffic delay.

Safe vehicles

Pre-impact pedestrian sensing technology is commercially available and may be appropriate for installation on the buses.

If quieter buses are used, the needs of visually impaired pedestrians will need to be considered. Technologies such as bus proximity alarms carried by pedestrians (perhaps as a smart phone application) could be envisaged, although technological dependency carries its own risk in the event of system failure.

Modifications in vehicle front-end design may minimise the severity of pedestrian injury should a crash occur.

The probability of conflict is loosely proportional to the number of vehicles. Therefore, use of higher capacity PT vehicles such as articulated buses or trams will reduce the number of vehicles without affecting the load carrying capacity. There will be significant route and network design implications with such a change in vehicle type.

Safe road use

Alert, compliant road users (both pedestrians and bus drivers) are a critical part of a safe system. Pedestrians have obligations and responsibilities for their own safety and should be aware of traffic risks while on this busy bus corridor.

With many school students increasingly being driven to school, younger pedestrians may not have appropriate road safety skills. Road safety training in schools could be developed beyond simple admonishments to look both ways before crossing streets to include practical skills for crossing roads, such as choosing an appropriate location.

Bus driver training programmes could be enhanced, for example to include more constructive attitudes than a “my space – your space” approach to road use. Practical instruction in advanced driving skills including collision avoidance and emergency braking could be instituted or intensified. Probably the most important message relates to speed management; buses travelling at or below the speed limit are less likely to hit pedestrians. The desire of drivers to maintain timetables could be offset by incentives for maintaining safer speeds, measured by the bus GPS units.

Conclusions

The Golden Mile traverses some of the most intense pedestrian and street activity space in Wellington. Developing safe system solutions to this important commercial, pedestrian and PT corridor may require a combination of approaches to “*provide a safe road system increasingly free of death and serious injury”*.

- A lower speed limit may be more appropriate given the constrained corridor width, high pedestrian numbers, and intervisibility issues;
- To manage bus speeds, the current on-street speed displays could be augmented with monitoring of bus GPS units to provide feedback and incentives to drivers;
- The "place" function of the Golden Mile is considered to be more important than the "movement" function and pedestrians should be given higher priority than public transport. Accordingly, buses could be considered as "guests" in that space, with drivers behaving as though pedestrians are the "owners" of the street;
- Any barrier should only be considered where intervisibility is an issue. A continuous unbroken barrier increases travel distance by preventing pedestrians from following the most direct line; therefore frequent gaps should be provided to enable legal crossings where intervisibility is sufficient;
- Any barrier should be positioned to provide enough space between the barrier and the kerb face to avoid pedestrian entrapment on the carriageway where they may be struck by a vehicle; and
- In the long term, if public transport cannot be operated in a manner compatible with the high levels of pedestrian activity on these streets, PT priority measures or exclusive bus or tram ways on other traffic corridors may need to be considered.

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