Austroads

Research Report
AP-R611-20

Integrating Safe System with Movement and Place for Vulnerable Road Users

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Prepared by

Bruce Corben

Project Manager

Luke Wilby and Melvin Eveleigh

Abstract

The Movement and Place Framework is increasingly used to guide transport planning in delivering a more integrated transport system to improve customer outcomes and support a range of user groups. Work is already underway in some jurisdictions to integrate Safe System principles and treatments within the Movement and Place Framework to safely cater for all road users and enable more proactive and lasting road safety benefits. This is particularly important for the liveability of places and vibrant streets, where greater numbers of pedestrians and cyclists gather. They are inherently more vulnerable in crashes and, in some environments, highly exposed to the risk of crashes.

This project has developed guidance for Australasian jurisdictions in ensuring, or transitioning to, safe use of roads and streets by pedestrians and cyclists. Road designers and system operators are encouraged to apply the guidance when designing new or redesigning existing roads and streets, and when making decisions about how these roads and streets will operate. The integration of Safe System aligned road elements for walking and cycling into the Movement and Place Framework aims to eventually eliminate deaths and serious injuries to pedestrians and cyclists on Australasian roads.

Keywords

Safe System, road safety, movement and place, vulnerable road users, pedestrians, walking, cyclists, bicycles, road design

ISBN 978-1-925854-71-8

Austroads Project No. SAG6130

Austroads Publication No. AP-R611-20

Publication date February 2020

Pages 131

Publisher

Austroads Ltd.
Level 9, 287 Elizabeth Street
Sydney NSW 2000 Australia
Phone: +61 2 8265 3300
austroads@austroads.com.au
www.austroads.com.au

About Austroads

Austroads is the peak organisation of Australasian road transport and traffic agencies.

Austroads' purpose is to support our member organisations to deliver an improved Australasian road transport network. To succeed in this task, we undertake leading-edge road and transport research which underpins our input to policy development and published guidance on the design, construction and management of the road network and its associated infrastructure.

Austroads provides a collective approach that delivers value for money, encourages shared knowledge and drives consistency for road users.

Austroads is governed by a Board consisting of senior executive representatives from each of its eleven member organisations:

- Transport for NSW
- Department of Transport Victoria
- Queensland Department of Transport and Main Roads
- Main Roads Western Australia
- Department of Planning, Transport and Infrastructure South Australia
- Department of State Growth Tasmania
- Department of Infrastructure, Planning and Logistics Northern Territory
- Transport Canberra and City Services Directorate, Australian Capital Territory
- The Department of Infrastructure, Transport, Cities and Regional Development
- Australian Local Government Association
- New Zealand Transport Agency.

Summary

The Movement and Place Framework is increasingly applied by jurisdictions to guide transport planning in delivering a more integrated transport system to support a range of customer outcomes and user groups. Work is actively underway in some jurisdictions to integrate Safe System principles and treatments within the Movement and Place Framework. This will lead to environments that safely cater for all road users and enable more proactive and lasting road safety benefits. This is particularly important for the liveability of places and vibrant streets, where there are greater numbers of pedestrians and cyclists. They are inherently more vulnerable in crashes, and crashes are more likely where vehicular movements dominate these environments without full consideration for other road users.

This project has developed guidance for Australasian jurisdictions in ensuring safe use of roads and streets by vulnerable road users, namely, pedestrians and cyclists. Safe use is defined here as designing and operating roads and streets, primarily in urban areas, according the principles of the Safe System. Guidance is provided on optimal 'Safe System' elements to improve the safety of pedestrians and cyclists for a range of street environments defined by the Movement and Place concept, as being applied in Australasia. Road designers and system operators should apply the guidance when designing new roads and streets, when redesigning existing roads and streets, and when making decisions about how these roads and streets will operate in their jurisdictions.

A functional definition of a comprehensive Movement and Place Framework was adopted. It consists of six broad Movement and Place 'families'. For each of these Movement and Place families, pedestrian and cyclist safety measures which are aligned with Safe System principles have been identified to guide jurisdiction practice. Identifying Safe System-aligned measures uses a practical, evidence-based definition of what constitutes Safe System performance for walking and cycling. The Movement and Place framework and the definition of Safe System-aligned road elements for walking and cycling have been integrated to provide guidance on the elimination of deaths and serious injuries to pedestrians and cyclists on Australasian roads.

A process for assessing the alignment of specific measures for pedestrians and cyclists with Safe System principles has been specified. It is based on the extent to which a measure or design form being considered for pedestrians and/or cyclists addresses the risks of:

- a severe injury (or death), given a crash
- the likelihood of a crash occurring, given the volumes of vehicles
- crashes due to the exposure of pedestrians and cyclists to traffic volumes.

Primary emphasis in assessing Safe System alignment is placed on the first of these three criteria, that is, the assessment of injury risk, in the event of a crash.

While the default position should always be to provide alignment with Safe System principles, it may not always be practical to deliver in the first instance when redesigning roads and streets. For such circumstances, further supporting infrastructure treatments are outlined. While these treatments alone won't achieve Safe System performance, they have the potential to reduce the road safety risks for vulnerable road users and assist in progressing towards a road environment free from death and serious injury. Importantly, when supporting measures are chosen because full alignment with Safe System principles is not feasible, it is highly desirable to select supporting measures which are on the trajectory to Safe System alignment, so that each incremental improvement is a progressive investment in the ultimate treatment.

The Movement and Place concept endeavours to integrate a wide and comprehensive range of attributes describing the use of a road or street, and the area within which it is situated. Because of this justified complexity, no typical cross section can be developed for any one street environment. For this reason, the pedestrian and cyclist infrastructure measures presented here have been identified because they are generically relevant to the different street environments and are aligned with Safe System principles. However, practitioners should consider the features of the specific street environment they are dealing with, as some measures may be impractical, of higher cost than less-effective alternatives or simply unsuited to the particular setting. By developing Movement and Place guidance for vulnerable road users that identifies optimal elements to improve their safety in each street environment, jurisdictions can create better and safer environments that accommodate the needs of all users.

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1. Introduction

1.1 Background

The Movement and Place (M&P) Framework is being increasingly applied by jurisdictions to guide the development of a more integrated transport system. Better integration supports a range of customer and user group outcomes. The emergence of the M&P concept has been driven by transport planners needing to give greater weighting to the multiple values of Place than in the past. Integration of Safe System principles and treatments within the M&P concept will lead to environments catering safely for all road users, enabling lasting road safety benefits from the outset.

As their many natural benefits are recognised by society, greater attention to the qualities of Place is vital for the liveability of urban places and vibrant streets, including in regional cities and towns, where walking and cycling are growing in popularity. Pedestrians and cyclists are highly vulnerable in crashes which, in turn, are more likely where vehicles are allowed to dominate environments without full consideration for all users.

This project seeks to synthesise evidence on the effectiveness of Safe System treatments for vulnerable road users (pedestrians and cyclists) in different street environments, and encourage all jurisdictions to apply this guidance locally.

By integrating a comprehensive set of attributes, the M&P concept provides direction on the uses of roads and streets, such as movement function and transport mode priorities, while attempting to take full account of the actual and desired future land uses. This process of integration is inherently complex, with no typical cross-section able to be developed for specific street environments/M&P combinations. The pedestrian and cyclist infrastructure measures presented here are aligned with Safe System principles and matched in general terms to individual M&P categories. However, practitioners must consider the specific suitability of individual measures to the street environment being considered to ensure that issues of practicality, cost and general suitability/alignment with the Place function are properly assessed. By developing M&P guidance, including appropriate levels of service for each mode, optimal elements can be determined to meet Safe System performance for vulnerable road users.

The default position should always be to deliver Safe System performing infrastructure from the start. However, where resources are limited or full Safe System is initially impractical, further supporting treatments, which may be appropriate in the interim, are also outlined. While these treatments alone won't lead to Safe System outcomes, they can help to reduce injury risks for vulnerable road users.

1.2 Methodology

The scope of the project spans all evidence-based research and guidance on implementation of the Safe System approach, particularly with regard to delivery of road safety infrastructure treatments, and on the M&P framework. Because pedestrian and cyclist activities and serious trauma are predominantly, though not solely, urban challenges, this report focusses on urban settings.

1.3 Report Structure

A clear understanding is required of the key concepts that need to be brought together to provide practical, evidence-based guidance on how to deliver Safe System aligned conditions for pedestrians and cyclists using various parts of the road transport system. This report comprises three main parts:

1. A functional definition of a comprehensive Movement and Place Framework.
2. A practical, evidence-based definition of what constitutes Safe System performance for road system elements designed to support safe walking and cycling.
3. A practical and robust guide on how to integrate the concepts described in 1 and 2, above.

2. Defining Movement and Place

At the commencement of this project, it was intended that the Movement and Place (M&P) Framework (Figure 2.1 below) set out in Austroads (2016a) would provide the basic definition and descriptions of the M&P concept. However, in early discussions with M&P subject-matter experts, it became evident that a great deal of work has been done since 2016 to enhance the early representations of the M&P concept. It is clear that much effort has been devoted, particularly in Victoria, New South Wales and the City of Auckland, to strengthening and extending the individual frameworks. At the time of finalising this report, NSW's Movement and Place Framework toolkit was being developed. It is also evident that other Australasian jurisdictions continue to develop and refine their frameworks. The frameworks evolving in each of these three jurisdictions are shown in Appendix A.

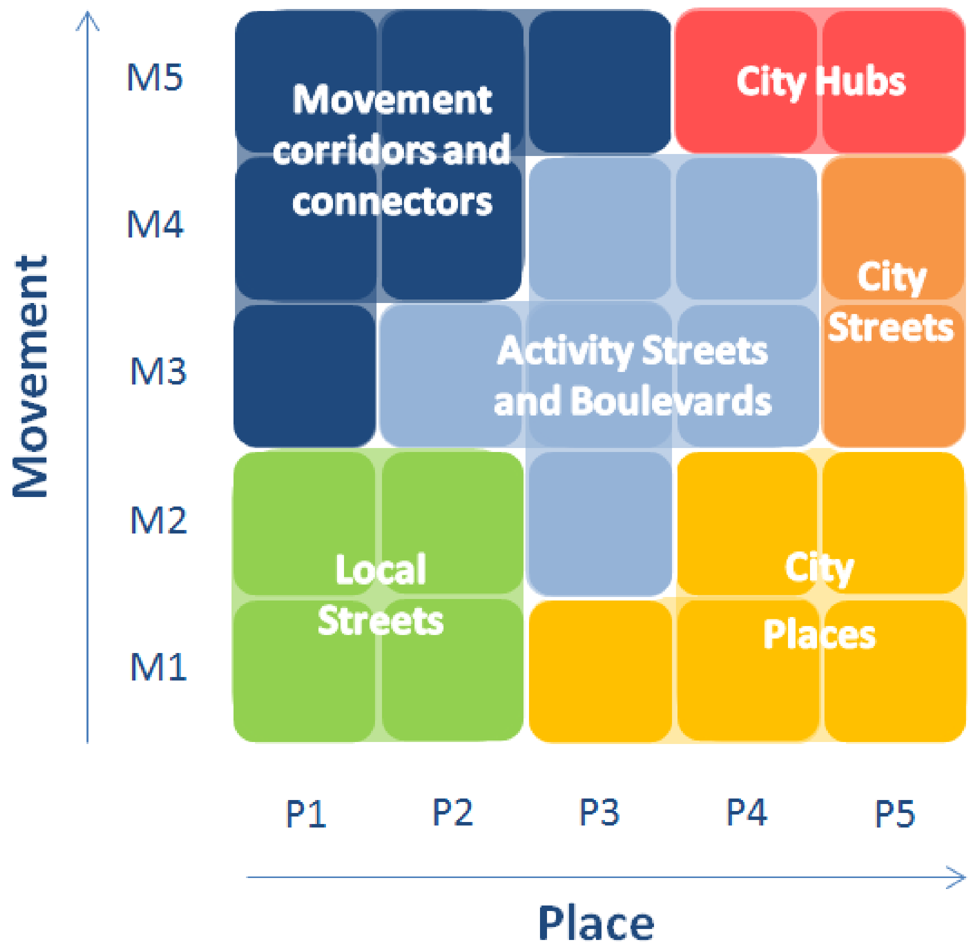
Figure 2.1: Movement and Place Framework

Source: Guide to Traffic Management Part 4: Network Management (Austroads 2016a)

While all of the frameworks in Appendix A are well-developed and increasingly comprehensive, they differ in important aspects, such as the number of categories defined by the framework. It was decided to choose the Victorian framework, largely because it is a simpler version comprising only six main M&P families. Simplicity is favoured for this initial exploration by Austroads into the task of mapping Safe System aligned elements for pedestrians and cyclists onto the M&P concept. The New South Wales and City of Auckland versions allow finer detail to be captured, with both defining nine M&P families. Finer grained categorisations can be addressed when further refining the work conducted under this project. Figure 2.1 shows examples of the types of roads and streets represented by the various M&P categories. More extensive sets of examples can be found in jurisdiction and city publications on M&P (e.g. Auckland Transport (undated) and DoT (2019).

The framework used in the report (Figure 2.2) is adapted from the Victorian model. This report uses Victoria's six road and street types, but departs from the Victorian model by numbering the axes so that M5 is the highest movement value and P5 the highest place value. The original Victorian framework, which uses M1 and P1 for its highest values, can be found at Appendix A.1.

Figure 2.2: Proposed Movement and Place framework showing road/street families



Having identified and defined a suitable M&P framework, a practical, evidence-based definition of Safe System performance is needed for road system elements designed to support safe walking and cycling. The basis for categorising measures as Safe System aligned or not, is described in Section 3.

2.1 Key Movement and Place Stereotypes for Pedestrians and Cyclists

Several main ways of grouping M&P categories have been developed; there are typically at least 25 unique combinations of Place (P1-P5) and Movement (M1-M5) values. Under some M&P definitions, P1 represents the highest value of place, while P5 the lowest. Similarly, M1 represents the highest value of movement and M5 the lowest. As noted earlier, this convention is counter-intuitive for some and therefore the practice of using higher numbers to indicate higher values has been adopted.

Victoria defines six general street categories or families that characterise Victoria's road and street network. These six families describe each broad category encountered in real-world experiences. A range of Safe System-aligned elements for pedestrians and cyclists are proposed in this report and illustrated with photographic examples for each of the key M&P stereotypes or families.

The reasons why certain elements are more suited to particular stereotypes than others are discussed, as are the attributes that align particular pedestrian or cycling measures with Safe System principles. Where available, effectiveness measures for individual pedestrian and cyclist safety measures are provided.

Figure 2.2 shows the 25 individual cells that form the M&P framework, with the six main families highlighted and positioned within the framework according to the particular combinations of their movement and place values. The six families in use are:

- City Hubs
- City Streets
- City Places
- Activity Streets and Boulevards
- Movement Corridors and Connectors
- Local Streets.

The following descriptions of these six M&P families appear in Department of Transport (2019).

City Hubs

Successful City Hubs are dense and vibrant places that have a high demand for movement. They are also places providing focal points for businesses and culture. City Hubs should aim to reduce the impact of high traffic volumes while accommodating high pedestrian numbers, multi-modal journeys and access to public transport and essential emergency services.

City Streets

Successful City Streets should provide a world class pedestrian friendly environment. They aim to support businesses, on-street activity and public life while ensuring excellent connections with the wider transport network.

City Places

City Places are roads and streets with high demand for pedestrian activities and lower levels of vehicle movement. City Places are places communities value and for people and visitors to enjoy.

Activity Streets and Boulevards

Successful Activity Streets and Boulevards provide access to shops and services by all modes. There is high demand for movement as well as place with a need to balance different demands within the available road space. Activity Streets and Boulevards aim to ensure a high quality public realm with a strong focus on supporting businesses, traders and neighbourhood life.

Movement Corridors and Connectors

Successful Connectors should provide safe, reliable and efficient movement of people and goods between regions and strategic centres and mitigate the impact on adjacent communities.

Local Streets

Successful Local Streets should provide quiet, safe and desirable residential access for all ages and abilities that foster community spirit and local pride. They are part of the fabric of our neighbourhoods, where we live our lives and facilitate local community access.

Regarding the evolution of the M&P concept, Austroads has commissioned work on classifying, measuring and valuing the benefits of place on the transport system (Project NEG6181). It is expected this project, being led by the New Zealand Transport Agency (NZTA), will provide further insight on integrating Safe System measures for vulnerable road users into Movement and Place (SAG6130).

2.2 Prioritising Modes

Department of Transport (2019) uses a nine-mode classification to guide prioritising the types of movements appropriate to each combination of M&P values. A hierarchy of classifications exists within each mode.

In the context of this report, the natural advantages of the walking and cycling (highly vulnerable) modes should not be overlooked. Cycling is a highly space-efficient mode of transport that can provide for large numbers of movements in a relatively narrow corridor, and has a lower negative impact on place (e.g., noise, pollution, space, etc.) than vehicular traffic. Furthermore, walking is the original, fundamental mode of movement that is healthy, sustainable, environmentally-friendly, is also space-efficient and causes negligible harm to others.

Walking (and to a lesser but significant degree, cycling) supports and links intrinsically to public transport, particularly trams and Light Rail Vehicles (LRVs), buses and rail, which are also to be encouraged because of their greater efficiency, support for healthy, active travel and long-term sustainability. These attributes are especially important for large and growing cities.

For high movement corridors, modern cities and towns would benefit greatly from the provision of parallel, physically-segregated, regional cycle networks in support of a high movement function for both cyclists and motorists, with safe crossing facilities for cyclists (and pedestrians) across these key routes. For city hubs, streets and places, world-class, separated cycling facilities are needed to facilitate active travel and promote the qualities sought from city places.

Figure 2.3: Mode Classification Types for Victorian Movement and Place framework)

Source: DoT 2019

3. Safe System

3.1 The Safe System Approach to Road Safety

Much has been written to describe the Safe System road safety vision, adopted in Australasia by Austroads in 2004. Section 3.1 sets out the interpretation of Safe System, as adopted by Austroads.

3.1.1 Opening Summary

Austroads (2018) states:

> *The Safe System approach is regarded as international best practice in road safety and provides an outcome whereby death and serious injury are virtually eliminated amongst users of the road system. Safe System is the management and design of the road system such that impact energy on the human body is firstly avoided or secondly managed at tolerable levels by manipulating speed, mass and crash angles to reduce crash injury severity.*

3.1.2 Key Principles

The Safe System philosophy and principles are a paradigm shift in road safety management, road transport management, road design and traffic management (Austroads 2017a, 2017b, 2019, Bliss & Breen 2013). By acknowledging that road users will inevitably make mistakes, and when they do, they should not be penalised with death or serious injury, it follows that road designers and operators have a shared responsibility to take appropriate actions to ensure that road crashes do not lead to fatal or serious injury outcomes.

The human body can only tolerate limited kinetic energy exchange before death and serious injury occurs. It is, therefore, critically important to design and maintain a forgiving road environment and infrastructure by taking into account human vulnerabilities and optimising all parts of the road system so that if one part fails, other parts are still there to protect people from fatal or serious injury crash outcomes. Safe System principles trigger a need to consider all the pillars of the road transport system (i.e. roads and roadsides, speeds, vehicles, users and post-crash care) in an integrated manner, as shown in Figure 3.1.

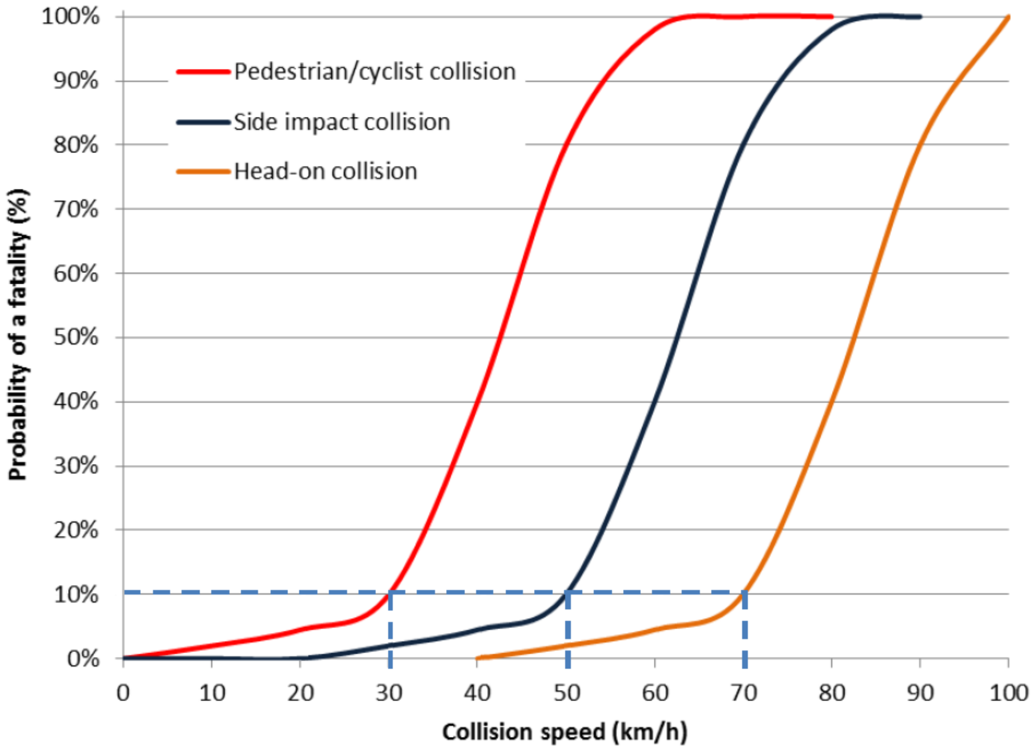
Figure 3.1: Representation of the Safe System

Austroads (2018) also states:

> *Often referred to as the Safe System Speeds, the following aspirational operating speeds are as follows:*
>
> - *30 km/h – Where there is the possibility of a collision between a vulnerable road user and a passenger vehicle*
> - *50 km/h – Where there is the possibility of a right angle collision between passenger vehicles*
> - *70 km/h – Where there is the possibility of a head on collision between passenger vehicles*
> - *≥100 km/h – Where there is no possible side or frontal impact between vehicles or impacts with vulnerable road users.*

An extension often added to the above scenarios is a 30 km/h threshold for a passenger vehicle in a side impact with a tree or pole. Note that at present there is only limited evidence on cyclist and motorcyclist injury thresholds and an assumption is often made that their injury potential is the same as the pedestrian curve. Figure 3.2 shows the relationships between collision speed and the probability of a fatality.

Figure 3.2: Relationship between collision speed and the probability of a fatality



Source: Austroads 2018

It is worthy of note that the Austroads compendium on the Safe System reflects most recent research, which, through crash analysis, appears to identify lower speed thresholds for the probability of serious injury for the same, and an extended range of, key crash types (Austroads 2018b).

As well as speed (and resultant energy), the impact angle as an influencing factor is also stressed, given that low-angle, merge-type impacts (say 20–30º) are considerably more survivable than, for example, head-on and right-angle (90º) impacts.

It follows that the separation of largely non-compatible road user types, or designs that provide for appropriate speeds and/or impact angles should an incident occur, will be safer than many traditional designs and will result in a greater alignment with the Safe System principles (also sometimes referred to as Safe System compliance).

3.1.3 The Importance of Speed

Safe speed is one of the four pillars of the Safe System. Speed is fundamentally important to crash and injury risk for all road users, but especially so for pedestrians and cyclists who have no protection in the event of a crash.

Traditionally, speed as a risk factor has been viewed primarily in terms of its effect on vehicle stopping distances. As shown in Figure 3.3:, the stopping distance of vehicle comprises two main parts:

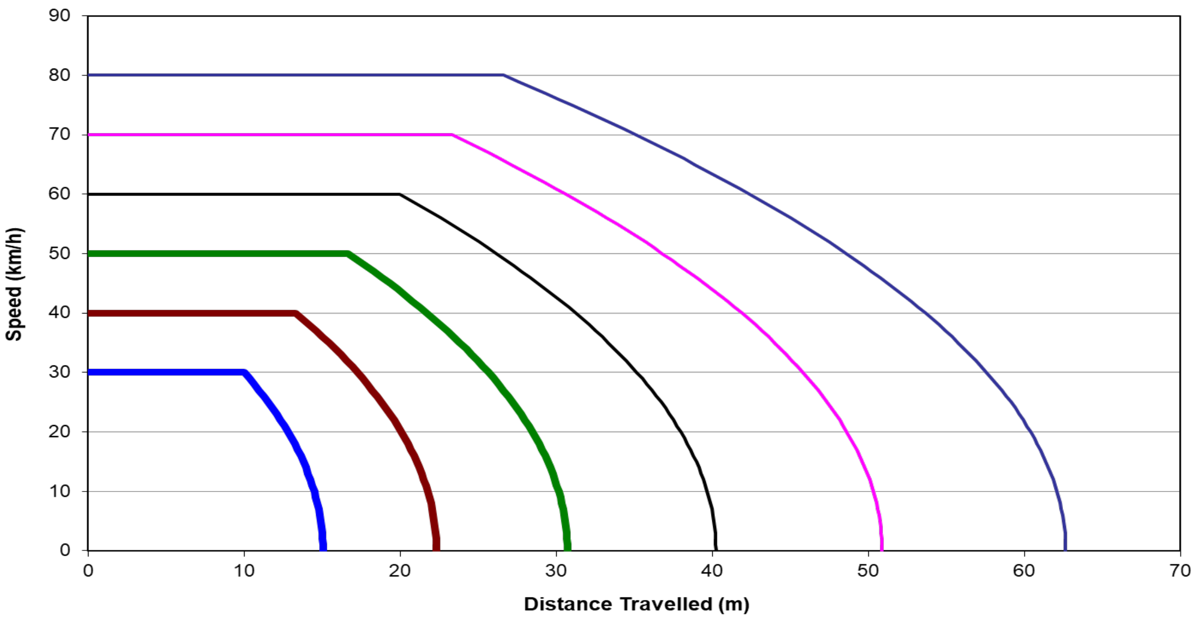
- **Perception-reaction time/distance** – the distance travelled by a vehicle while the driver perceives the need to stop and then to react by activating the brakes. Typical durations for drivers are in the order of 1.2 to 1.5 seconds, but can be considerably longer for drivers who are distracted, inattentive, drowsy, slowed by age or otherwise performing below population averages.

- **Braking distance** – the distance required by a vehicle to come to a stop, from the point where the brakes were applied. These distances are determined by physics, and in particular the initial speed of the vehicle. They can be calculated using the equation $v^2 = u^2 + 2*\mu*g*s$, where v is the final speed ($m.sec^{-1}$), u is the initial speed ($m.sec^{-1}$), μ is the coefficient of friction of the road surface, g is the gravitational constant ($9.8\ m^{-2}$) and s the distance travelled while braking (m). When transposed, the equation becomes $s = v^2-u^2/2*0.7*9.8$, for a typical coefficient of friction of 0.7.

When graphed for a range of initial speeds on the vertical axis, the effects on total stopping distance (i.e., the sum of perception-reaction distance and braking distance) can been seen in Figure 3.3: Stopping distances of typical passenger cars for a range of initial travel speeds (calculations assume a coefficient of friction of 0.70 and a driver perception-reaction time of 1.2 seconds). Of particular note are the observations that:

- Perception-reaction distances are linearly related to the initial travel speed, that is, doubling the initial speed leads to a doubling of the perception-reaction distance.
- Braking distances have a second power (i.e., squared) relationship with initial speed. That is, doubling the initial speed increases the braking distance fourfold.
- A driver travelling in a car at 30 km/h can stop for a pedestrian or cyclist in around 15m. A driver travelling at the urban default speed limit of 50 km/h can stop in around 31 metres and will still be travelling at 50 km/h when the vehicle reaches the hypothetical pedestrian or cyclist in the vehicle's path when it reaches the conflict point at a distance of 15m. This impact speed coincides with a low chance of a struck pedestrian or cyclist surviving (refer Figure 3.3, below).
- For higher travel speeds, as is commonly encountered of roads which have a high movement function, the chances of vulnerable road users struck at these speeds surviving is even lower.
- For slower perception-reaction times (e.g., for impaired drivers) and/or for road surfaces with below average coefficients of friction, the risk for vulnerable road users rise even further.

Figure 3.3: Stopping distances of typical passenger cars for a range of initial travel speeds (calculations assume a coefficient of friction of 0.70 and a driver perception-reaction time of 1.2 seconds)



Theoretical assessment of travel speeds, based on vehicle stopping distances and human biomechanical limits to impact forces (Corben, D'Elia and Healy, 2006) indicates that fatal injury risk to a pedestrian:

- reduces by 75-80% when a driver chooses to travel at 30 km/h instead of 40 km/h
- reduces by 90-95% when a driver chooses to travel at 30 km/h instead of 50 km/h
- reduces by 75-80% when a driver chooses to travel at 40 km/h instead of 50 km/h.

The *Guide to Road Design Part 3: Geometric Design (*Austroads, 2016c) uses perception–reaction times from 1.5 seconds (highly alerted) to 2.5 seconds and co-efficient values of 0.36 (normal conditions) to 0.61 (dry conditions, low traffic volumes) for cars and 0.29 for trucks. The perception-reaction times 1.2 secs reaction time and coefficient of friction of 0.7 used in Figure 3.3, lead to much shorter stopping distances than those assumed in the Guide to Road Design Part 3. To avoid over-estimating the degree of safety from a particular design, stopping distances have been recalculated for a perception-reaction time of 2.5 and a coefficient of friction of 0.36.

Under these more conservative assumptions, stopping distances increase very substantially compared with the perception reaction time of 1.2 seconds and a coefficient of friction of 0.7. For each of the following speeds, stopping distances effectively double, increasing from:

- 63 to 126 metres at 80 km/h
- 40 to 81 metres at 60 km/h
- 31 to 62 metres at 50 km/h
- 22 to 45 metres at 40 km/h.

This means that not only is crash risk substantially increased, because of the doubling of stopping distances but so too will impact speeds be much higher, resulting in large increases in the risk of severe injuries.

While corresponding fatality risk curves as a function of impact speed are not as well-developed for cyclists as for pedestrians, it is believed reasonable to adopt the same or similar risk curves for cyclists as for pedestrians. The research has yet to be conducted to verify this, however, it is judged a reasonable and conservative assumption for use until more reliable findings are available.

It is common practice for full- or part-time 40 km/h speed limits to apply around schools in most Australasian jurisdictions. As has been noted later in this report (Section 4.7.5.1 on local streets), the evidence linking speed with pedestrian crash and injury risk is strong. It is also well-understood that children, because of their immaturity, lack of experience, relative unpredictability in traffic and their generally smaller stature, are at heightened crash risk. This combination of risk factors suggests that consideration should be given to further reducing the inherent levels of risk to pedestrians and cyclists in the vicinity of schools by using 30 km/h instead of the current 40 km/h limits.

3.1.4 Road Policing

The Safe System recognises that road policing in its various forms, particularly the enforcement of driver and rider compliance with speed limits, is a vital component in the vision to eventually eliminate deaths and serious injuries from Australasian roads. Both general deterrence and the issuing of infringements play important parts, and will continue to be required into the longer term future, at least until many of the high-risk behaviours undertaken by today's drivers and riders can be automatically enforced, or prevented through vehicle technology. Road policing can be regarded as providing targeted support to road users to meet their part of the shared responsibility principle that characterises the Safe System.

Examples of treatment types that depend on driver and rider compliance include pedestrian operated signals, intersection signals and zebra crossings. Despite extensive efforts over long periods, there remains a behavioural problem of red light running by drivers and riders, failure to give way to pedestrians at zebra crossings, failure by right-turning drivers to give way to cyclists at intersection signals and a problem of pedestrians failing to comply with pedestrian signal displays. Seeking to achieve full compliance by road users at these types of control has been only partly successful. Even with the known deterrent effects of traffic policing and the use of automated enforcement methods, such as speed cameras and combined red light and speed cameras, which can halve the number of deaths and serious injuries, a substantial residual risk remains at conventional traffic control devices, especially for pedestrians and cyclists.

It is essential to recognise the limitations on human behaviour and performance, and on vehicle crashworthiness and crash avoidance in devising the types of matched infrastructure and speed combinations needed to deliver Safe System aligned roads and streets. Matching infrastructure and speed to deliver Safe System-aligned roads and streets is the primary focus of this project.

3.1.5 Innovative Mobility Devices

A wide variety of innovative mobility devices has emerged in the personal transport market. They range from e-scooters and e-skateboards, to e-bikes and motorised mobility devices for people with health challenges restricting their mobility. With the growth in urban traffic congestion, the desire for sustainable, independent forms of transport, the ageing of our societies and the decline in aspects of population health, such as obesity and related illnesses, innovative mobility devices may well rise in importance as a legitimate transport mode and as a component of severe road trauma.

Operating on road, innovative mobility devices will be characterised by significant speed differentials compared with motor vehicles. Large differences in mass and direction between these devices and conventional traffic add to the safety concerns.

While these emerging types of user were not included in the scope of this project, they are referred to from time to time in this report. The regulatory framework for their integration into the (mainly) urban road transport system has not been fully defined, which makes it problematic to deal with them comprehensively in this project. They are noted here, however, as a priority for future refinement of the integration of Safe System aligned measures for vulnerable road users within the M&P Framework.

3.1.6 The Role of Standards and Guidelines

The integration of transport planning and land use planning disciplines, using the M&P Framework, is a relatively new concept to Australasia. Similarly, the formal adoption of the Safe System in 2004 signalled the beginning of a paradigm shift in thinking (ITF, 2016), particularly in regard to the laudable ambition of designing and operating the road system to eventually eliminate deaths and serious injuries from Australasian roads. It is not surprising that traditional approaches to road and traffic engineering, and to land use and other planning functions, are still in the process of aligning fully with the M&P framework and with the Safe System vision for road safety.

Compared with the extensive history of road and traffic engineering as a professional discipline in Australia and New Zealand, Safe System-aligned design and operation is still evolving. As a consequence, a considerable amount of review and fine-tuning of existing design standards and traffic engineering practices is required to achieve the profound lift in ambition. The required changes are taking time and energy to achieve. While this transition phase is underway, the application of ‘context sensitive design’ will sometimes be needed, along with the adaptive use of standards and guidelines to achieve Safe System risk levels. In this context, adherence to standards and guidelines should not be used as rationale for not striving for Safe System outcomes. Rather, opportunities must be taken to build upon or adapt the current standards and guidelines to assure low-risk use of the road transport system.

Where applicable and consistent with the key Safe System principles described for each treatment, readers are referred to the latest Austroads design guides for more detailed information on design parameters. A number of relevant Austroads reports (Austroads, 2016c, Austroads, 2017a, Austroads, 2017c, Austroads, 2017d and Austroads, 2019) are cited in the list of references (Section 6).

3.2 Assessing Safe System Alignment

The science of assessing road design and traffic engineering/management measures with respect to their alignment with Safe System principles is evolving. Methods based on the management of exposure, crash likelihood and management of kinetic energy at impact, have been applied in this project:

- the concept of the Visionary Research Model and the Kinetic Energy Management Model, or KEMM (Corben et al., 2010 and Corben, 2005)
- the Safe System Assessment Framework (Austroads, 2016b).

Transport and Main Roads (TMR) Queensland reports successful use of the Dutch Sustainable Safety principles, identified in Austroads (2015) on Safe Systems in the Planning Process. It has been found by TMR to be a scientifically defensible method for developing infrastructure for vulnerable road users that is consistent with the Safe System. This approach has been received well by practitioners and helped to address the limited experience and knowledge amongst practitioners on how to apply Safe System thinking.

While there are obvious advantages in building upon current practices in individual jurisdictions, the use of alternative approaches, such as the Dutch Sustainable Safety, are entirely compatible in the principles adopted and presented in this report. They are simply articulated in a different form. In essence, the criteria used to assess alignment with the Safe System focus on:

- the risk of a severe outcome, given a crash
- the risk of a crash for a given level of exposure
- exposure as a measure of opportunities for crashes to occur, due to vehicles, pedestrians and/or cyclist being on the same roads, more or less at the same time.

In the case of the KEMM, the risk of a severe outcome, given a crash, can be further examined according to the amount of kinetic energy involved, the way in which it is dissipated during a collision and the human biomechanical tolerance to the violent forces sometimes experienced in crashes.

Applying these principles to pedestrian and cyclist measures provides a scientific, evidence-based method for assessing the degree of alignment of individual measures with Safe System principles. In general, measures that are highly effective either in:

- separating vehicles from vulnerable road users, or
- securing impact speeds at or below the Safe System ‘boundary condition’ for pedestrians and cyclists,

are considered aligned with the principles of the Safe System.

While the overall numbers of pedestrians, cyclists and motor vehicles are rising markedly with population growth and urbanisation, there are valuable opportunities to address exposure by achieving a mode shift from, for example, private car travel to public transport and/or by redistributing vehicular traffic away from busy pedestrian and/or cyclist routes to routes where fewer interactions between vulnerable road users and vehicles will occur. To avoid confusion with the practical interpretation of the above criteria, treatments such as grade-separation are not deemed to reduce risk through exposure reduction (the same number of road users, possibly more, will still use the location), but rather by taking way the likelihood of crashes as a result of vertical separation of movements.

By way of further clarification, some types of treatment have been identified as reducing exposure, even though their primary mechanism of effect may be through reductions in crash likelihood and/or injury severity, given a crash. To illustrate, safety platforms at or between intersections reduce both crash risk and injury severity because they act on speed, which has the dual effects of aiding crash avoidance and reducing impact speed in crashes that do occur. For drivers who don’t like being slowed, some may divert to alternative routes, thereby also reducing exposure to crash possibilities.

It is increasingly accepted by road safety practitioners that, to be aligned with the Safe System philosophy for pedestrians and cyclists, 30 km/h impact speeds define the upper limit of an ‘acceptable’ collision. This ‘Safe System boundary condition’ coincides with an approximate 10% chance of the struck pedestrian being killed by the collision. Put another way, this corresponds to a 90% chance of survival. For the corresponding situation with serious injury (i.e., a collision with a pedestrian producing a 10% chance of serious injury), a much lower impact speed applies. While the research on the risk of death or serious injury to cyclists is less extensive, for practical purposes, the same value of the boundary condition has been adopted. Figure 3.2 shows the general shape of the curves defining pedestrian fatality risk as a function of impact speed.

There remains some contention among researchers about whether 30 km/h accurately defines the boundary condition for Safe System risk levels. The contention centres largely on experimental methods used in collecting data on crashes and the potential for bias in sampling. Numerous research studies have been undertaken on this topic and, while each has strengths and weaknesses, overall there is a lack of clear and precise consensus.

Scott and Mackie (undated) reviewed past studies on the relationships between pedestrian death and serious injury risk levels and impact speed. While noting that general safety outcomes have improved considerably over recent decades, since the earlier studies were undertaken, it was concluded that the original risk curves presented by Wramborg (2005) still appear indicative of the general shape of the fatal injury risk relationships as a function of speed at impact.

Jurewicz et al. (2016) present risk curves that suggest pedestrian-vehicle impact speeds of around 20 km/h should not be exceeded if Safe System criteria are to be met. This is based on the same criteria used here:

- injury severity, given a crash, is proportional to impact speed
- crash likelihood affected by road geometry and road user behaviour
- exposure to crash risk is proportional to average traffic flows.

Logan, Corben and Lawrence (2019), after reviewing the main studies on the probability of a fatality as a function of impact speed, favoured the use of risk curves for fatal and combined fatal/serious injury for impact less than or equal to 70 km/h (after Davis, 2001), while also acknowledging the methodological shortcomings of past studies. At impact speeds of 30 km/h, the adopted curve indicates that:

- the risk of a fatality is around 3% for pedestrians aged 60+ years
- the risk of a fatality or serious injury is around 25% for pedestrians aged up to 60 years
- the risk of a fatality or serious injury is around 70% for pedestrians aged 60+ years.

ITF also discussed the lack of clarity with research in the field and recommended the adoption of 30 km/h as the target Safe System speed, until more robust research comes to light.

The ITF report notes that:

> *Whilst there is, and will continue to be, considerable debate on safe impact speeds and the shape of various fatality risk curves, precise definitions are not possible or meaningful in reality. They represent some form of population average over a sizeable number of cases but there is considerable variability in outcomes, and hence risk, among individuals due to uncontrollable factors such as the type and size of the vehicle, the age and health status of the road user, the point of impact, etc. There is a certain randomness about these factors that is often beyond the control of the system designer or operator. Because of this variability in the incidence and circumstances of real world crashes, a conservative position should be adopted concerning risk so as to account for a broad range of population, vehicles and conditions. We must also be cognisant that the use of fatality risk curves, and the tenth percentile value to determine safe impact speeds, is by definition permitting the incidence of some deaths and serious injuries, notwithstanding the commitment to eradicating deaths and serious injuries from road crashes.*

Given the need for a pragmatic decision on this issue, 30 km/h is regarded as an appropriate, practical threshold to use, until such time as more reliable estimates emerge. In reality, a lower threshold could legitimately be considered to accommodate the greater vulnerability of older people, young children and people with disabilities, or where the striking vehicles are large and/or have unforgiving frontal designs (e.g., trucks, trams and utilities fitted with bull bars).

Research carried out by Anderson et al. (1997) found that about half of all fatally injured pedestrians in their study were struck at the initial travel speed; that is the driver had not braked before impact. This means that the travel speed is commonly the impact speed. For these reasons, pedestrian and cyclist measures should, ideally, be designed and operated to secure impact speeds to not more than 30 km/h.

Other measures, not fully-aligned with Safe System principles, can be deployed to help improve safety for pedestrians and cyclists. However, given that New Zealand, Australia and its jurisdictions are on the journey to zero deaths and serious injuries – some are even setting 2050 as the year for achieving (close to) zero – the aim, wherever possible, should be to provide Safe System aligned measures from the start. Selecting Safe System aligned designs and forms of operation from the beginning will prevent a great deal of avoidable trauma to pedestrians and cyclists during the period over which the target of zero is being pursued. An ambitious approach from the outset also avoids investing inefficiently, in multiple stages, to achieve, ultimately, Safe System risk levels.

A list of measures to improve safety for pedestrians and cyclists was created and assessed according to each measure's ability to deliver Safe System outcomes. The final selection of measures deemed to be aligned with Safe System principles was the subject of consultation with working group members across Australasia. It was noted in the consultation process that some measures can be regarded as Safe System aligned, in their own right, while others could become Safe System aligned as a result of future vehicle technology and/or when combined with other measures that assure impact speeds occur within the Safe System 'boundary condition' for cyclists and pedestrians.

Given the importance of and challenges in defining what constitutes Safe System design and operation, consideration could be given as to additional value in developing a new form of the Safe System Assessment Framework that more explicitly accommodates M&P concepts as part of the assessment criteria.

3.3 Safe System Aligned Measures for Pedestrians and Cyclists

The alignment of measures with Safe System principles, as described below, is based on the extent to which individual measures affect:

- injury severity, given a crash
- crash likelihood
- exposure to crash risk.

This ensures consistency with past Austroads work in the field, particularly the Safe System Assessment Framework (Austroads, 2016b) and compatibility with the Safe System ideal that no one should be killed or seriously injured, given that mistakes cannot be eliminated from system use.

Appendix B describes Safe System-aligned measures for pedestrians and cyclists. Each measure is accompanied by a rating of the extent to which alignment is achieved. The rating is comprised of the above three elements: severity, given a crash, crash likelihood and exposure. Multiple ticks under each of these elements indicates that the particular mechanism of effect is strong. No ticks mean no or a negligible effect

Outlined below in Table 3.1 and Table 3.2 are listings of pedestrian and cyclist safety measures. They are regarded as fully-aligned with the principles of Safe System performance. Others listed in Section 3.4 are designed to contribute to improved safety and/or mobility, but their safety performance falls short of Safe System risk levels. The method used to assess alignment with Safe System performance is described in Section 3.2. In addition, guidance on this attribute of pedestrian safety measures was provided by Makwasha, Turner and Jurewicz (2017).

An added safety advantage of providing well-designed (safe and convenient) pedestrian and cyclist facilities is that crash likelihood, which is affected, in part, by the expectations of drivers of encountering vulnerable road users, should be reduced. Priority treatments help to raise driver awareness and lift expectations of the potential for conflict with pedestrians and cyclists. Vulnerable road users may also be attracted to use safe and convenient crossing locations provided, and similarly, riders may be attracted to use well-designed cycling facilities.

Table 3.1: Listing of pedestrian and cyclist safety measures at intersections and alignment with Safe System principles

At intersections									
Safe System treatment	**Exposure**	**Likelihood**	**Severity**	**City Hubs**	**City Streets**	**City Places**	**Activity Streets & Boulevards**	**Movement Corridors & Connectors**	**Local Streets**
Signalised intersections with 'Scramble' phasing (30 km/h speed limit)		✓	✓	✓	✓		✓		
Limit access by mode	✓	✓	✓	✓		✓			
Raised signalised intersections with 30 km/h ramps		✓	✓	✓	✓		✓		
Safety platforms (30 km/h or lower) on all approaches		✓	✓	✓	✓	✓			✓
Geo-fencing technology for trams, trucks and other large vehicles		✓	✓	✓	✓	✓	✓		
Signalised roundabout with exclusive turn phases for public transport, cyclists and pedestrians		✓	✓	✓			✓	✓	
Grade-separation of pedestrians and cyclists from vehicular traffic		✓		✓					
Roundabouts with 20/30 km/h wombat crossings		✓	✓		✓	✓	✓	✓	✓
Threshold platforms at intersections with side-streets		✓	✓	✓	✓	✓		✓	
Raised intersections with 30 km/h (or lower) platforms		✓	✓	✓	✓	✓	✓	✓	✓
Signalised 'tennis ball' intersections (30 km/h design)		✓	✓					✓	
All-way stop signs		✓	✓			✓		✓	✓
Restricted access intersection	✓	✓	✓			✓		✓	✓

Table 3.2: Listing of pedestrian and cyclist safety measures grouped by location type and alignment with Safe System principles

Between intersections									
Safe System treatment	**Exposure**	**Likelihood**	**Severity**	**City Hubs**	**City Streets**	**City Places**	**Activity Streets & Boulevards**	**Movement Corridors & Connectors**	**Local Streets**
30 km/h speed limits or lower		✓	✓	✓	✓	✓	✓		✓
Fully segregated pedestrian paths		✓		✓	✓	✓		✓	
Separated cycle facilities		✓		✓	✓	✓	✓	✓	
Car-free streets (potentially time-based)		✓		✓		✓	✓		
Pedestrian operated signals, Zebras or Wombats in 30 km/h (or lower) speed zones		✓	✓	✓	✓		✓		✓
Shared space (with raised textured pavements and 10 km/h speed limits)		✓	✓	✓	✓	✓	✓		✓
Relocation of public transport stops from centre of road to kerbside		✓	✓	✓					
Pedestrian malls	✓			✓		✓	✓		
Grade-separation of pedestrians and cyclists from vehicular traffic		✓		✓				✓	
Shared use by cyclists of traffic lanes (30 km/h)		✓	✓		✓				✓
Kerb blisters/road narrowing/pedestrian refuges	✓	✓			✓	✓			✓
General road narrowing (30 km/h setting)	✓	✓			✓	✓			✓
Exposure reduction/redirection of through traffic/time-based restrictions on selected modes	✓				✓				✓
Medians		✓					✓		
Playground zones (30 km/h setting)		✓	✓			✓			✓
On-road cycle lanes (30 km/h setting)		✓	✓			✓			✓
On-road cycle lanes with physical separation		✓✓		✓	✓		✓	✓	✓
Wombat crossings (30 km/h)		✓	✓			✓			✓
Speed platforms (30 km/h)		✓	✓			✓			✓
Horizontal deflection (30 km/h setting)		✓	✓			✓			✓
Textured/coloured pavements (30 km/h setting)		✓	✓			✓			✓
Grade-separated roundabouts for pedestrians and cyclists, e.g., Hovenring, Eindhoven, Netherlands			✓					✓	

3.4 Supporting Treatments for Pedestrians and Cyclists

There are additional pedestrian and cyclist safety measures, not fully-aligned with Safe System thinking, which can be regarded as supporting and/or making incremental improvements. Measures not fully-aligned with Safe System principles tend to operate with higher travel speeds and rely on crash avoidance, which result in higher risk to pedestrians or cyclists in the event of a crash.

3.4.1 Criteria for Alignment with Safe System

As noted earlier, Safe System-aligned measures for pedestrians and cyclists require either full separation of pedestrians and cyclists from vehicles or, where this cannot practically be achieved, low-risk travel speeds, typically not exceeding 30 km/h. This assessment method is based on the extent to which design and operational combinations meet the following three key criteria:

- injury severity
- crash likelihood
- exposure to potential conflict.

Full separation, by definition, eliminates the likelihood of crashes, while travel speeds not exceeding 30 km/h help to ensure impacts at legal speeds have a low risk of death or severe injury to vulnerable road users. Travel speeds not above 30 km/h are vital to achieving the lowest practical risk levels for several reasons:

- In a highly complex traffic setting, drivers and riders may reach the threshold of their information processing capabilities if travelling at high speed. At 30 km/h or less, decisions can be made in a much more timely fashion.
- Driver willingness to give way increases with reductions in travel speed. Thus the frequency of conflict between motorists, and pedestrians and cyclists, can be reduced further at lower travel speeds compared with legal speeds commonly encountered today.
- Vehicle stopping distances are substantially reduced with lower travel speeds.
- Past research on pedestrian safety (McLean, 1997) shows that in about half of all pedestrian fatalities, no braking occurred and therefore the travel speed is too often the impact speed. This is likely to be true for cyclists as well.
- The research on the biomechanical tolerance of humans to various vehicle impact speeds (Logan, Corben and Lawrence, 2019) shows a rapid rise in the risk of a pedestrian (or cyclist) fatality above an impact speed of around 30 km/h. For serious injury risk, the corresponding threshold impact speed is likely to be much lower. Risk is even more acute when the striking vehicle is a tram/LRV or other large vehicle and/or when children and older people are involved.

3.4.2 Supporting Treatments and 30 km/h Speed Limits

Many of the most commonly encountered treatments for pedestrians and cyclists cannot be considered to be Safe System-aligned, largely because they are designed in a way that allows crashes to occur at speeds outside the Safe System boundary conditions for unprotected road users. Typical examples of supporting treatments include:

- push-button pedestrian signals
- dwell on Red signals
- zebra crossings
- kerb outstands
- medians

- intersection signals
- pedestrian refuges
- horizontal deflections
- coloured or textured pavements
- street-lighting
- 40 or 50 km/h speed limits
- raised intersections (40 or 50 km/h)
- speed platforms (40 or 50 km/h)
- highlighted pedestrian cross-walks
- fully controlled right and/or left turn traffic signal phases
- turn bans/restrictions
- roundabouts with zebras
- roundabouts with splitter islands
- intersection signals with 40 or 50 km/h platforms
- countdown timers
- early start signals
- auto activation of pedestrian phases
- intelligent pavement markers
- ‘scramble’ signal phasing
- intersection approach islands
- area-wide 40 km/h speed limit reductions
- static warning signs
- surface skid resistance
- cyclist phases at traffic signals
- traffic calming features for cyclists (40+ km/h speed environment)
- overhead projection of safety messages onto pavements
- intelligent pavement markers
- optimal sight lines (adequate but not excessive)
- cul-de-sac streets (to limit exposure).

If measures not fully-aligned with Safe System were to be coupled with lower speed limits, for example, in the range of 30-40 km/h, and supported with effective speed-moderating infrastructure, many could be reclassified as being Safe System-aligned.

Safe System-aligned measures should be afforded highest priority by the road designer, the town/urban planner or the transport planner in developing ideas and working with their counterparts in allied disciplines.

3.4.3 Pedestrian Fencing

Roadside fencing has been used extensively over past decades to prevent pedestrians crossing at risky locations and also to provide a level of protection for pedestrians from errant cars and trucks, especially where traffic lanes are close to footpaths. This practice has been found to be in conflict with both the value of Place and the promotion of walking and active travel. As a result of this practice, pedestrians are often required to detour hundreds of metres to cross a road that might be just 15 to 20 metres wide. This has proved inconvenient for pedestrians, especially those who are older and/or mobility-impaired. As a result, walkability of areas is impacted and the quality of Place has tended to decline.

Pedestrian fencing could, however, be regarded as Safe System-aligned under some circumstances. Short sections of fencing or other barrier, such as street-scaping, may be beneficial to pedestrian safety if located to prevent crossing in high-risk locations. For example, pedestrians who cross on the immediate approach or departure sides of intersection signals often do so at acute risk. On the lead up to intersection signals, where vehicles queue awaiting a green signal, it is common for pedestrians to be struck as they make their way through the stationary lanes before encountering a lane of moving vehicles. In these circumstances, pedestrians will often be obscured by other vehicles from the view of approaching drivers and riders.

Any proposal to use extended lengths of pedestrian fencing should consider how it may impact on safety and walkability, especially in settings with high place values. On roads of high movement value and low place value, fencing may be appropriate. However, where fencing is used, provision should be made for safe and acceptable alternatives. It is most important to avoid requiring pedestrians to walk long distances to cross urban roads, even if these roads do perform a Movement Corridor and Connector function.

To support place-making, substitutes for fencing, such as the planting of trees, hedges and low level vegetation, the positioning of public seating and public art, the provision of bicycle parking and the use of contrasting surfaces can be effective in directing pedestrians to cross at locations of lower crash risk. When well-designed, in both aesthetic and functional terms, pedestrian movements can be positively influenced without creating the negative sense of impeding pedestrians in their natural choices of where to cross.

3.4.4 Tactical Urbanism

Tactical urbanism has been described as introducing low-cost, temporary changes to the built environment, usually in cities, intended to improve local neighbourhoods and city gathering places (Pfeifer, 2014). Tactical urbanism techniques are being used increasingly in cities and towns, especially in North America, to accelerate the pace of change. New York, San Francisco, Seattle, Memphis, Vancouver, Christchurch and Auckland have been early adopters of tactical urbanism approaches. They can be adapted to take many forms, including changes to the way in which traffic signals operate by time-of-day or day-of-week, changing the layout of streets for selected days, such as weekend events when traffic demand is lighter, or more permanent changes based on affordable trials to test or demonstrate ideas before investing in the more costly permanent form. Figure 3.4, Figure 3.5 and Figure 3.6 show examples from the City of New York.

Figure 3.4: Example of Tactical Urbanism in the City of Christchurch New Zealand

Figure 3.5: Example of Tactical Urbanism in the City of New York

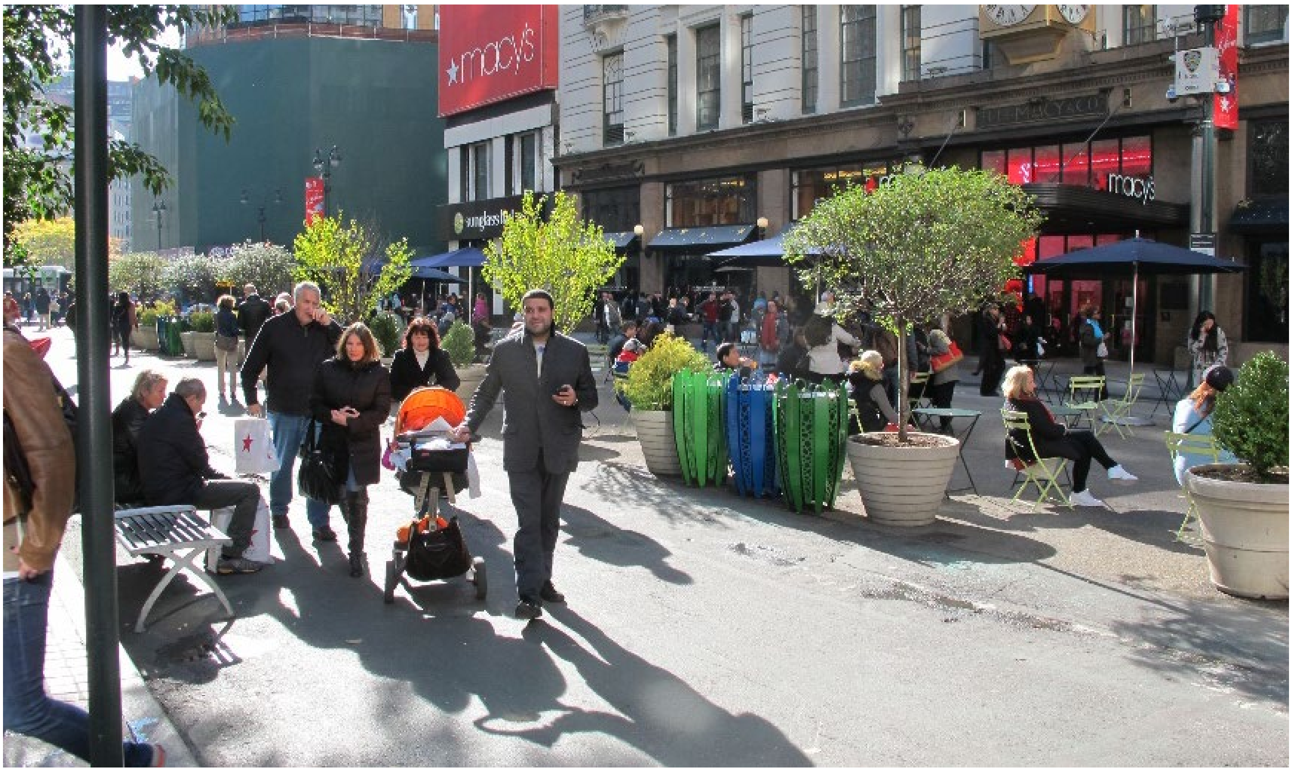


Figure 3.6: Example of Tactical Urbanism in the City of New York

Tactical urbanism is in its infancy as a highly innovative means of making cities and towns more liveable, vibrant and sustainable, at a faster pace than has been possible using traditional processes. Given this emphasis, it appears to have potential for finding solutions to the safe integration of the many innovative mobility devices appearing on city streets. As well as creating space for people to gather in and enjoy urban settings, highly innovative forms of tactical urbanism may assist with creating the space for safe use of roads and streets by the diverse array of mobility devices, such as e-scooters, bikes and skateboards, and motorised devices for the mobility-impaired.

4. Mapping Pedestrian and Cyclist Safety onto the Movement and Place Framework

4.1 Basic Approach

To help in defining and understanding the path for moving from the somewhat abstract concepts of Movement and Place (M&P) to real-world application, six stereotypical examples of each of the six M&P families have been examined in terms of their appropriateness of the objectives of this project.

The Safe System speed limit for pedestrians and for cyclists has been established at 30 km/h. Impact speeds above these values are understood to result in a rapid rise in the risk of severe injury, or even death, to the struck pedestrian or cyclist. A speed limit of 30 km/h provides a strong base upon which to build low risk conditions for pedestrians and cyclists. An important part of the challenge is to provide the infrastructure required to make compliance with the 30 km/h speed limit the natural choice of drivers and riders.

Theoretical assessment based on vehicle stopping distances and human biomechanical limits to impact forces (Corben, D'Elia and Healy, 2006) indicated fatal injury risk to a pedestrian reduces by:

- 75-80% when a driver chooses to travel at 30 km/h instead of 40 km/h
- 90-95% when a driver chooses to travel at 30 km/h instead of 50 km/h
- 75-80% when a driver chooses to travel at 40 km/h instead of 50 km/h.

While comparable fatality risk curves as a function of impact speed are not as well developed for cyclists as for pedestrians, it is believed reasonable to adopt the same or similar risk curves for cyclists as for pedestrians. While the research has yet to be conducted to verify this, it is judged a reasonable and conservative assumption for use until more reliable findings are available.

While 30 km/h speed limits in local streets offer the simplest and lowest cost means of designing for Safe System risk levels for pedestrians and cyclists, the current default speed limit is 50 km/h and there is little evidence of the political level allowing the profession to reduce the default urban speed limit to 40 km/h. Even at 40 km/h, significant investment in infrastructure is needed to secure travel speeds in local streets to genuinely low risk levels for pedestrians and cyclists.

There has been long-standing discussion and debate about the long-term effectiveness of introducing lower speed limits in local streets (i.e., below the 50 km/h urban default) without also constructing supporting traffic-calming infrastructure. One approach to reducing travel speeds to 30 km/h, at minimum costs, which could be trialled would involve:

- Introducing area-wide 30 km/h speed limits (or 40 km/h if a staged approach is preferred), while recognising that many drivers will comply, regardless of whether they support the initiative. This shift in behaviour will bring average speeds down and, hence, immediately lower crash and injury risk. Other measures, such as enforcement and public education, can be used to support non-compliant drivers and riders to comply. Area-wide speed limits will reduce the proliferation of signing, which can be an unsightly feature of neighbourhood streets, where visual amenity is highly-valued by residents.
- Monitoring speeds post-treatment (i.e., introduction of 30 km/h area wide speed limits) to see where speed behaviour requires further attention.
- Where further attention is needed, introducing traffic- calming treatments at the entrance to individual areas and/or within areas to address locations of 'systemic' risk, such as at intersections which are, of course, locations where crash risk is highly concentrated. By treating intersections to bring speeds down, not only will speeds be reduced at these locations, but speeds on local streets, between intersections, will also be addressed.

- By continuing to monitor speeds on neighbourhood streets and, only where needed, adding more traffic-calming infrastructure (or other measures, such as mobile speed feedback signs).

Keys to success with a 30 km/h (or lower) speed limit in settings where pedestrians and cyclists are prioritised include:

- conveying to the public the simple message that 30 km/h speed limits are a proven, highly cost-effective measure to reduce crash and injury risk, especially to pedestrians and cyclists
- even without full compliance, average travel speeds fall and the risk of severe injury falls even more markedly. When viewed at the generational level, compliance with speed limits is likely to improve steadily over time
- supporting active travel and, therefore, population health
- reducing society's reliance on private car travel, thereby reducing congestion/green-house gases
- improving amenity and liveability by providing low-risk access to a wide array of modes and road user types
- the duty-of-care of a road authority to their system users is met.

Some pedestrian and cyclist measures described in Section 4 are not currently used in the relevant case study, but are considered generically applicable to the relevant M&P family, rather than being judged to be specifically suited to the particular case study. However, practitioners should consider the features of the specific M&P setting, as some measures may be impractical or simply unsuited to the setting. The measures presented in Section 4 are drawn to attention because they are aligned with Safe System principles. It has been assumed that all options under each M&P family would be designed and operated to ensure the safety of pedestrians and cyclists, with relative priority assigned to various modes according to the importance of the combination of movement and place. A more comprehensive list of treatments and examples can be found in Appendix B.

As noted earlier, while achieving a Safe System transformation for pedestrians and cyclists should be the approach of first-choice, this will not always prove practical and supporting measures may ultimately need to be selected. Where supporting measures are accompanied by lower speed limits, closer alignment with Safe System principles will be achieved.

For the measures considered suitable for each M&P family, an indication of typical costs is provided. The number of $ symbols is *indicative* of unit costs, with the following convention applied:

- $ - up to $10k
- $$ - $10k to $100k
- $$$ - $100k to $1m
- $$$$ - $1m to $10m
- $$$$$ - over $10m.

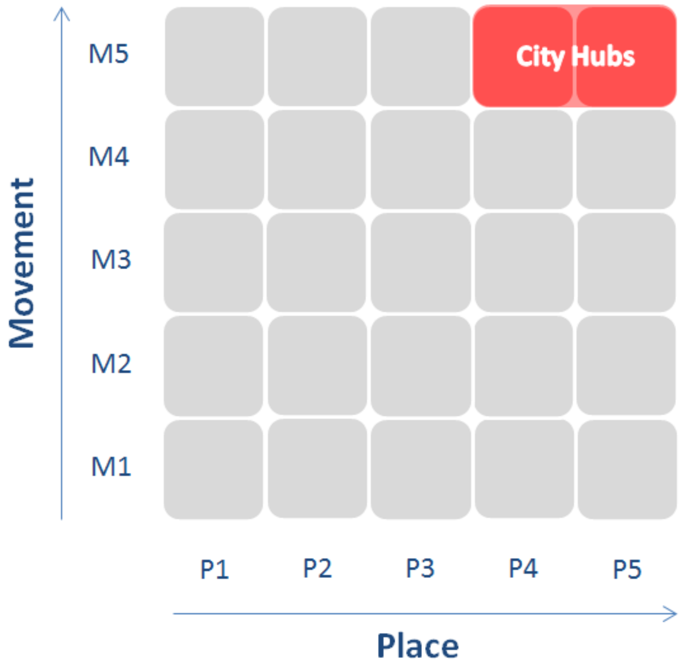
The process for mapping pedestrian and cyclist measures onto each of the six M&P categories is now described, using a suitable case study from an Australasian jurisdiction.

4.2 City Hubs

4.2.1 General Description

Successful City Hubs are dense and vibrant places that have a high demand for movement. They are also places providing focal points for business and culture. City Hubs should aim to reduce the impact of high traffic volumes while accommodating high pedestrian numbers, multi-modal journeys and access to public transport and essential emergency services. (DoT 2019).

Figure 4.1: City Hubs on the Movement and Place Framework



4.2.2 Key Movements in City Hubs

The key movement considerations in City Hubs are outlined below. From a vulnerable road user perspective, the priority is to avoid potentially harmful conflicts between any combinations of these modes, especially turning-vehicles which often dominate general traffic movements.

- Pedestrians: Significant numbers, both accessing the City Hub as a final destination and also moving through and across the environment as they travel between destinations and transport interchanges.
- Cyclists: Significant and growing numbers, including delivery services within the City Hub.
- Public Transport: Major interchange, potentially including multi modal (tram/LRV, train, bus, ferry). It is important to note that this potentially introduces large vehicles into the traffic setting, as well as leading to pedestrians interacting in this complex environment for the first time in their journey.
- General traffic: Significant numbers, both accessing the City Hub as a final destination (including taxi and ride-share) and also moving through and across the city.
- Freight: Significant numbers, delivery drivers and construction/service vehicles.
- Other: Significant numbers of motorcyclists due to extensive parking within the City Hub, and other small mobility devices.

While the existing conditions in some City Hubs afford a significant degree of priority to general traffic and/or freight, the application of M&P thinking may gradually lead to a greater emphasis on the value of Place in City Hubs and a downplaying of incompatible movement priorities.

4.2.3 Key Places in City Hubs

The key place features of City Hubs are outlined below. Demand is likely to be spread across the day and week, with peaks concentrated around business hours and on weekends.

- places of employment
- entertainment, retail and restaurant precincts
- recreation facilities and open spaces
- special event venues such as sporting stadiums
- major transport interchanges.

4.2.4 Safe System Measures for Pedestrians and Cyclists in City Hubs

Based on the above, Safe System-aligned measures for pedestrians and cyclists that could be considered for City Hubs are described below and summarised in Table 4.1.

Only the higher priority measures are discussed in further detail in this section, and references for the other measures can be found in in Appendix B.

Table 4.1: City Hubs – Summary of Safe System aligned pedestrian and cyclist measures

Safe System treatment	Indicative cost
At intersections in City Hubs	
Signalised intersections with 'Scramble' phasing (30 km/h speed limit)	$$
Limit access by mode	$$
Raised signalised intersections with 30 km/h ramps	$$$
Raised intersections with 10 or 20 km/h ramps	$$$
Geo-fencing technology for trams, trucks and other large vehicles	$$$
Signalised roundabout with exclusive turn phases for public transport, cyclists and pedestrians	$$$$
Grade-separation of pedestrians and cyclists from vehicular traffic	$$$$$
Between intersections in City Hubs	
30 km/h speed limits or lower	$
Fully segregated pedestrian paths	$$$
Full segregated cycle paths	$$$
Car-free streets (potentially time-based)	$$$
Pedestrian operated signals, Zebras or Wombats in 30 km/h (or lower) speed zones	$$$
Shared space (with 10 km/h speed limits)	$$$$
Relocation of public transport stops from centre of road to kerbside	$$$$
Pedestrian malls	$$$$
Grade-separation of pedestrians and cyclists from vehicular traffic	$$$$$

While Table 4.1 proposes signalised roundabouts as a potential Safe System-aligned treatment for City Hubs, they may not be desirable in City Hubs that are spatially-constrained. However, signalised roundabouts need not be space-intensive in settings where walking and cycling are the high priority modes and neither general traffic nor freight movements are being prioritised. Compact forms of signalised roundabout may be able to be developed for these situations. Also, some City Hubs may already be reasonably spacious and able to accommodate a signalised roundabout. The space created could potentially be used to enhance place-making (e.g. through the provision of seating, tree-planting and other features).

Another more general measure that is applicable both at and between intersections involves limiting the times freight and service vehicles can access areas. This initiative acts to reduce exposure of pedestrians and cyclists in high activity times to the more threatening vehicle types using city streets.

Some of these measures are described more fully following the stereotypical case and, where feasible, illustrated with photographs or other image types. All treatments are covered in more depth in Appendix B.

A Stereotypical Case – Melbourne

Below is a description of the concept and principles applied to the intersection of Flinders and Swanston Streets, and for the relevant road sections that are situated within the City Hub category. Figure 4.2 below shows the area using a Google satellite image.

The Flinders Street and Swanston Street City Hub serves a vital role in commercial and community activities, such as shopping, access to employment and study, the conduct of businesses of many kinds and places for people to socialise. To support these intense activities and land uses, this City Hub must perform a crucial transport function. A major focus of this area of Melbourne is to move large numbers of people in a safe and efficient manner. This entails prioritising access to, and the efficiency of, public transport operations.

An integral part of prioritising public transport services is also to prioritise walking, as this is an essential part of using public transport. There is a high density of commercial activity, including shopping, employment and general business activities. As a consequence, high-quality walking and cycling facilities, and public transport services, are needed to support the intended and dominant forms of land use. The movement of private and commercial vehicles is generally of lower priority relative to the prioritisation of social, business and commercial activities, and therefore the need for high-quality facilities and services for active travel. Thus, the modes that should receive high-priority in and around Flinders and Swanston Streets are:

- walking
- cycling
- public transport services (trains, trams and buses)
- interchange facilities which link tram and bus services with Flinders Street Railway Station.

Other modes, namely general traffic, freight (other than local goods deliveries), and motorcycling routes and tourist-related traffic would typically be assigned lower priority within City Hubs.

Figure 4.2: Google satellite image Intersection of, and approaches to, Flinders and Swanston Streets Melbourne

(Downloaded 2 September 2019)

Figure 4.3: Intersection of Flinders and Swanston Street Melbourne, with Flinders Street Station visible in the background

Walking, cycling and tram movements

Pedestrian activity in and around the Flinders and Swanston Streets intersection is intense and sustained for at least eighteen hours of an average weekday. Even on weekends, activity is high though no longer dominated by work and study-related travel, but rather by entertainment, shopping, dining, and attendance at nearby galleries, and high-capacity sporting events and concerts, and the like.

The Flinders Street Railway Station is a major generator of pedestrian activity, while the tram services that operate on both Swanston Street and Flinders Street are among the busiest and most vital to Melbourne's public transport system. Both modes generate high levels of pedestrian activity, strongly influenced by morning and evening commuter peaks. Together, rail and tram services function as a major transport interchange, where a safe and efficient connection between modes is highly-valued by public transport users. Notwithstanding the dominance of peak periods, the area is a genuine hub for pedestrian and public transport activity throughout the day and well into the night. After train and tram services cease each day, activity drops but remains substantial.

Swanston Street carries large and growing numbers of commuter cyclists, especially to and from Melbourne's south-eastern suburbs. International and national tourist activity is also evident, largely through the use of share-bikes docked in the vicinity. A variety of highly-significant land uses exists on all four corners of the intersection; in addition to the Flinders Street Railway Station, the nationally significant Federation Square, St Paul's Cathedral and the historic hotel, Young and Jackson's, occupy the other three quadrants of the intersection. Numerous other major land uses and generators of pedestrian and related activity dominate the surrounding area.

In this M&P setting, pedestrians, cyclists, public transport (trams and buses) and interchanges are prioritised. Treatments for pedestrians and cyclists are presented in terms of their alignment with Safe System principles or their potential to serve as a supporting treatment or one that can make a worthwhile contribution to pedestrian and/or cyclist safety. Measures are grouped according to their application at intersections or along roads and streets between intersections.

4.2.5 Safe System Priority Treatments

To avoid death to or serious injury being sustained by a pedestrian or cyclist negotiating an intersection, it is fundamentally important that vehicle travel speeds do not exceed 30 km/h. If this can be achieved, together with a low risk of a crash occurring, Safe System risk levels will have been achieved for these two highly vulnerable and rapidly growing road user groups.

Speed limit setting

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

City Hubs have both a high movement value and a high place value. In the case of Flinders and Swanston Streets, the high movement value manifests itself primarily in the need to move very high volumes of pedestrians, trams and a growing number of cyclists. Given that general traffic and freight are not prioritised, other than to provide access to businesses, car parks and the like. With this context, lower travel speeds are to be favoured as they support low-risk walking, cycling and access to and from rail, trams and other public transport options in the City Hub.

At intersections – grade-separation of pedestrians and cyclists from vehicular traffic

Injury Severity	Crash Likelihood	Exposure to Conflicts
	✓✓✓	

In this particular case study, grade-separation could be designed to create a seamless link between rail and tram services, thereby eliminating the need for many pedestrians to cross wide city streets and consequently be exposed to crash risk. Such a facility would create a better modal interchange experience for public transport passengers and reduce delays, as well as improving access to and from the city centre and giving higher priority to vehicular through-traffic. The mechanism for reducing the risk of pedestrian (or cyclist) crashes is to reduce crash likelihood through vertical separation, while exposure remains unchanged or, in some circumstances, may actually rise due to use of the facility by larger numbers of vulnerable road users.

Design issues to consider are:

- minimising/carefully managing level changes, with special attention to mobility-impaired users
- creating direct links aligned with pedestrian desire lines to maximise convenience and likelihood of their use
- integrating tunnels/overpasses into rail stations and tram stops, with potential to provide direct underground connections between rail platforms and centre-of-the-road tram stops
- Integrating connections between tram and train services within a larger commercial development could include, for example, shops, residential accommodation and offices.

Figure 4.4: Perth rail station which connects trains with shops and offices via an elevated walkway

Raised signalised intersections with 30 km/h ramps

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

The incorporation of a raised intersection profile (or plateau) into an intersection signal design has the potential to be transformational in achieving Safe System risk levels. The achievement of 50 km/h travel speeds leads to a high chance (around 90%) of vehicle occupants surviving a side-impact crash. However, for this same speed environment, a pedestrian or cyclist would have an approximate 10% chance of surviving. This is why travel speeds through busy intersections in City Hubs should remain below 30 km/h. While not a primary effect, raised intersections may, in some cases, lead to fewer vehicles using the intersection, to avoid the possible perception of some drivers that they may experience increased delay. To further reduce the likelihood of crashes with pedestrians, traffic signals can be designed and operated to ensure pedestrians and cyclists receive signal phases, for example, ‘Scramble’ crossings that separate them from all vehicular traffic. There are numerous notable examples of ‘Scramble’ crossings across Australasia. Tram services in the Flinders and Swanston Streets City Hub would receive priority over general traffic movement, while the relative priority between trams, walking and cycling would be influenced by current demand, and the desired future state.

Figure 4.5: Raised signalised intersection in Dubai (many such intersections are equipped with Red Light and Speed Cameras operating on all approaches

Signalised intersection with 'Scramble' phasing (30 km/h speed limits)

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	

Without changing exposure, intersection phasing that does not allow vehicle movements while pedestrians are crossing will sharply reduce crash likelihood and, when travel speeds are constrained to low levels (i.e., not more than 30 km/h), manage injury risk to acceptable levels. 'Scramble' phasing of signals, which is particularly appropriate for high pedestrian activity areas, achieves this objective when accompanied by infrastructure designed to achieve low travel speeds. While referred to here as 'scramble' crossings, some jurisdictions may be more familiar with the 'Barnes Dance' terminology. Australian and Canadian examples of scramble crossings are show in Figure 4.6 and Figure 4.7.

Figure 4.6: 'Scramble' pedestrian crossing, George/Park Streets Sydney NSW

Figure 4.7: 'Scramble' pedestrian crossing, Banff, Alberta, Canada

Between intersections

Injury Severity	Crash Likelihood	Exposure to Conflicts
	✓✓✓	

Separation of cycling from vehicular traffic is also potentially appropriate in a City Hub where cycling is a prioritised mode of travel. Separated cycle facilities can take a number of forms, depending on the legal designation of the facility, available space and other requirements at the specific location. While separation is, by definition, highly effective in eliminating conflict, there will be places where cyclists come into conflict with vehicles and/or pedestrians. This type of facility acts almost entirely on crash likelihood, as the numbers of drivers and riders will typically remain unchanged (they may even increase), and the speeds of both cyclists and motorists will also remain largely unchanged. Where the conflicts involve pedestrians, these locations of conflict must be managed to ensure low-risk speeds by vehicles and also by cyclists. Separate cyclist phases where cyclists meet roadways can aid with separation.

Figure 4.8: Separated bicycle path (Intersection of Kent and Druitt Streets Sydney)

Pedestrian operated signals, zebras or wombats in 30 km/h (or lower) speed limits

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Pedestrian operated signals, and zebra and wombat crossings provide a high level of protection to crossing pedestrians, where the designs are accompanied by speed platforms aimed at travel speeds of 30 km/h or below. In some circumstances, such as along tram or light rail routes, provision of platforms that meet these speed requirements may be difficult. In these circumstances, it is highly desirable that the speed limit be set to 30 km/h (or less) and infrastructure measures to secure such speeds are also provided where practical. Space can often be provided for on-road cycle lanes which are deemed to be Safe System aligned when the speed setting is effectively at or below 30 km/h.

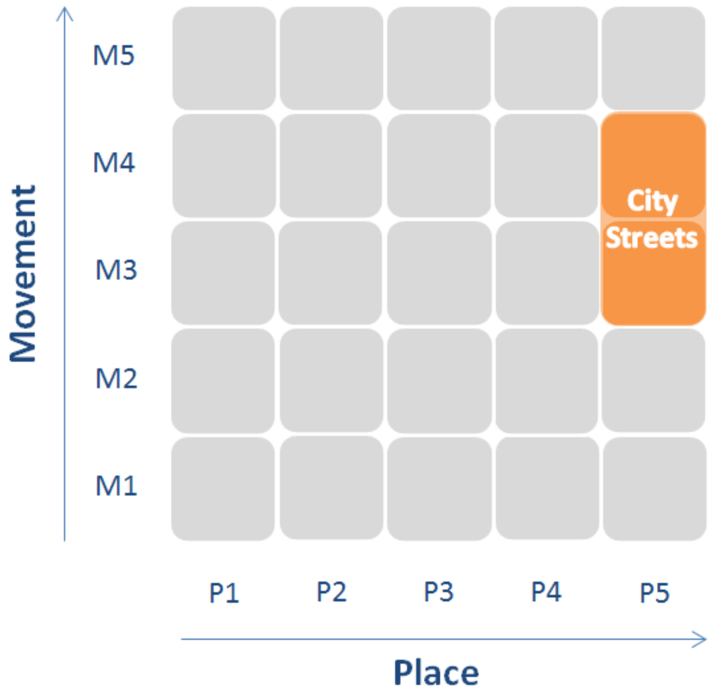
Figure 4.9: Wombat crossing (City of Port Phillip, Melbourne)

4.3 City Streets

4.3.1 General Description

Successful City Streets should provide a world class pedestrian friendly environment. They aim to support businesses, on-street activity and public life while ensuring excellent connections with the wider transport network (DoT 2019).

Figure 4.10: City Streets on the Movement and Place Framework



4.3.2 Key Movements in City Streets

The key movement considerations in City Streets are outlined below:

- Pedestrians: Significant numbers, both accessing City Streets as a final destination and also moving through and across the environment as they travel between destinations and transport interchanges.
- Cyclists: Significant and growing numbers, including delivery services within City Streets.
- Public Transport: high quality connections to public transport are needed for City Streets to meet their primary objectives of ensuring excellent connections with the wider transport network.
- General traffic: Significant numbers, both accessing City Streets as a final destination (including taxi and ride-share) and also moving through and across the city.
- Freight: Significant numbers, delivery drivers and construction/service vehicles.
- Other: Significant numbers of motorcyclists due to extensive parking within City Streets, and other small mobility devices.

4.3.3 Key Places in City Streets

The key place features of City Streets are outlined below. Demand is likely to be spread across the day and week, with peaks concentrated around business hours and on weekends.

- places of employment

- entertainment, retail and restaurant precincts
- recreation facilities and open spaces
- special event venues such as sporting stadiums
- Major transport interchanges.

4.3.4 Safe System Measures for Pedestrians and Cyclists in City Streets

In support of the movement priorities listed above, the design and operation of City Streets seeks to provide a world-class pedestrian-friendly environment, as well as supporting businesses, on-street activity and public life while ensuring excellent connections with the wider transport network (refer to general description above).

In general, City Streets have relatively high movement values and significant freight volumes, as noted in section 4.3.2 above. This is incompatible with the notion of cyclists and vehicles attempting to share the same space. Therefore, cyclist facilities that provide separation from general and freight traffic should be favoured over designs that result in sharing traffic lanes. Where this is not spatially feasible, the emphasis must be on assuring low travel speeds as a means of minimising risk and avoiding crashes above 30 km/h. Even at this Safe System boundary speed, cyclist and pedestrian deaths can still occur (e.g., through cyclists and/or pedestrians being run-over by cars, trucks, buses or trams). Older people are especially susceptible to this type of crash in City Streets

With the above qualifications, Safe System-aligned measures for pedestrians and cyclists that could be considered for City Streets are summarised in Table 4.2 and described in the following sections. The number of $ symbols is indicative of typical unit costs.

Table 4.2: City Streets – Summary of Safe System aligned pedestrian and cyclist measures

Safe System treatment	Indicative cost
At intersections in City Streets	
Threshold platforms at intersections with City Streets	$
Signalised intersections with ‘Scramble’ phasing (30 km/h speed limit)	$$
Raised signalised intersections with 30 km/h ramps	$$$
Signalised intersections with 30 km/h safety platforms	$$$
Signalised intersections with 10 or 20 km/h safety platforms	$$$
Geo-fencing technology for trams, buses trucks and other large vehicles	$$$
Roundabouts with 30 km/h wombat crossings	$$$
Between intersections in City Streets	
30 km/h speed limits or lower	$
Shared use by cyclists of general traffic lanes (30 km/h)	$
Wombat crossings	$$
Kerb blisters/road narrowing	$$
General road narrowing	$$$
Exposure reduction/redirection of through traffic	$$$
Fully segregated pedestrian paths	$$$
Fully segregated cycle paths	$$$
Shared space (10 km/h)	$$$$

Some of these measures are described more fully following the stereotypical case and, where feasible, illustrated with photographs or other image types. All treatments are covered in more depth in the earlier section on Safe System treatments and in Appendix B.

A Stereotypical Case – Hobart

Hobart is a small-sized Australian capital city situated on the Derwent River in the southern region of Tasmania. The greater Hobart area has a population of around 220,000, with the City of Hobart comprising around 50,000. Tourism is one of the major industries in Tasmania, with much of the tourist activity centring on Hobart, and its popular coastline and inland attractions.

Liverpool Street, between Elizabeth and Murray Streets, a distance of almost 200 metres, is an example of City Street where pedestrian activity has been prioritised in recognition of the high place value and the need to support a range of land use activities, as well as pedestrian and cyclist safety. Liverpool Street is lined on both sides with shops, cafes, financial institutions and other businesses that draw high levels of pedestrian and vehicular activity. The layout of Liverpool Street in the Hobart city network is shown in Figure 4.11.

Figure 4.11: Google satellite image of Liverpool Street between Elizabeth and Murray Streets, Hobart

(downloaded 28 August 2019)

In a City Street, such as Liverpool Street, the following modes would receive priority:

- pedestrians and cyclists
- buses
- interchanges between pedestrians and bus services (or other public transport serving the area)
- access for general traffic
- access for delivery vehicles, emergency services and general service vehicles, such as for waste removal, maintenance of utility services, construction vehicles, etc.
- freight, other than local goods deliveries, and motorcycling routes and tourist-related traffic (other than pedestrian traffic) would typically be assigned lower priority within a City Streets setting.

Pedestrian, cycling and tram movements

Within Liverpool Street, pedestrian movements are primarily along the footpaths, with a demand for crossing movements of Liverpool Street anywhere along the entire length. The desire by pedestrians to cross anywhere throughout the length is a reflection of the varied nature of commercial development along this section of Liverpool Street. Shops of numerous types are situated along the length, on both sides of the street, creating the desire and opportunity to switch from one side of the road to the other to visit shops and other commercial premises in a convenient sequence as pedestrians move along the street. Reinforcing this behaviour is the fact that the distance from one side of the road to the other is quite short, making it more attractive and practical to cross according to convenience, rather than walking up one side of the road to a set of intersection signals and returning along the other side to the premises of interest. This form of pedestrian behaviour is strongly evident in City Places and in Activity Streets and Boulevards.

Those cyclists using Liverpool Street and having a destination in the shopping and commercial area will want to park their bikes and then become pedestrians until their visit has been completed. They will return to their bikes on foot and become cyclists again, leaving the street by riding along it or turning into side-streets. Other cyclists may not have a destination in Liverpool Street and are simply using the street to gain access to another part of the city or as part of a longer journey. For this form of riding, it may be desirable to make provision for cycling on other routes that are better suited to the rider’s needs and safety levels.

In this M&P setting, pedestrians, cyclists, public transport (buses) and interchanges are prioritised. Bus services operate in nearby adjacent streets. While general traffic and freight would not be prioritised in a City Street setting, providing access for these vehicle types, under low risk conditions for pedestrian and cyclists, is a priority. Treatments for pedestrians and cyclists are presented in terms of their alignment with Safe System principles, or their potential to serve as either a supporting treatment or one that makes a worthwhile contribution to safety. Measures are grouped according to their application at intersections or along roads and streets between intersections.

Liverpool Street operates one-way from Elizabeth Street to Murray Street and has a speed limit of 30 km/h over this length. The default urban speed limit of 50 km/h applies along other sections of Liverpool Street. Continuous footpaths exist throughout. They have been widened in recent years to create less crowded conditions for pedestrians in this busy area. As a consequence of footpath widening, the roadway that has to be negotiated by crossing pedestrians is narrower and therefore of lower crash risk. The one-way operation of Liverpool Street means that pedestrians need to select a safe gap in only one direction of travel, rather than a safe coincident gap in two directions. Parking exists on both sides of Liverpool Street which, while providing better access for motorists and their passengers, interferes with sight lines between pedestrians and drivers.

On-street car parking also presents an added risk to cyclists, by creating opportunities for car-doors to be opened into the path of approaching cyclists. The main reduction in the risks faced by cyclists using Liverpool Street comes from the reduction in speed limit from the original default of 50 km/h to the new limit of 30 km/h. This change in speed environment not only reduces differential speeds between drivers and riders but, moreover, acts to reduce the absolute speeds should a crash occur. Figure 4.12 shows Liverpool Street facing South-West from Elizabeth Street, at the start of the 30 km/h speed limit. In additional to the duplicate 30 km/h speed limit signs:

- the “30” numerals are painted on the traffic lane to reinforce the lower speed limit
- lateral road pavement markings are painted to create the perception of a narrowing of the traffic lane; this would likely elicit lower travel speeds from entering drivers/motorcyclists
- the lateral pavement markings have been supplemented with yellow, circular raised markers to provide tactile and audible cues to drivers entering a changed street environment.

A section of Liverpool Street between Elizabeth and Murray Streets has been narrowed through a combination of general footpath widening and construction of kerb blisters. Figure 4.14 shows the narrowed length of Liverpool Street that operates as a one-way street, with a single traffic lane, lateral pavement markings, roadside bollards, tree-planting and street furniture, such as public seating and rubbish bins.

Figure 4.12: Liverpool Street, Hobart, facing South-West from Elizabeth Street

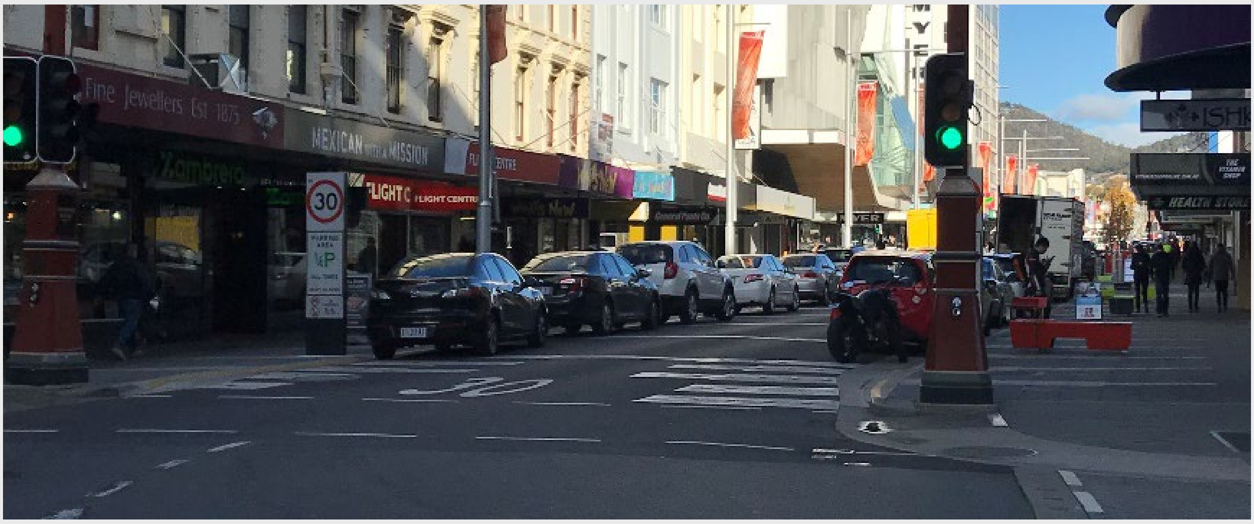


Figure 4.13: Liverpool Street, Hobart, facing South-West towards Murray Street

Figure 4.14: Narrowed section of Liverpool Street, Hobart, facing South-West towards Murray Street

4.3.5 Safe System Priority Treatments

To avoid death or serious injury being sustained by a pedestrian or cyclist negotiating an intersection, it is fundamentally important that vehicle travel speeds do not exceed 30 km/h. If this can be achieved, together with a low risk of a crash occurring, Safe System risk levels will have been achieved for these two highly vulnerable and rapidly growing road user groups.

Speed limit setting

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

In Liverpool Street, the emphasis is on facilitating pedestrian and cyclist movements, and on providing *access* by cars and delivery vehicles, rather than generating high vehicle movements through the city. For the reasons outlined in earlier sections, speed limits of 30 km/h or lower are generally appropriate for City Streets. Setting higher limits has the proven effect of elevating risk to the pedestrians, cyclists and other vulnerable road users. Each 10 km/h increase in speed limit substantially reduces the survivability for pedestrians and cyclists in the event of a crash. While not a primary mechanism of improving safety, lower speed limits (i.e., 30 km/h) may have the effect of reducing exposure by redirecting motorists who seek higher travel speeds to alternative routes.

At intersections

As noted above, 30 km/h has become the Safe System threshold impact speed for pedestrians and cyclists. Because braking by drivers occurs in only about half of all pedestrian fatalities, it is important to ensure travel speeds do not exceed 30 km/h. If travel speeds can be constrained not to exceed 30 km/h, ideally in combination with a low risk of crashes, the conditions for Safe System risk levels will have been created for these two highly vulnerable and prioritised road user groups.

Traffic signals exist at either end of the section of Liverpool Street in this example. In both cases, travel speeds of 50 km/h are legally permissible through the intersections. Red light running by drivers and riders, and non-compliance with traffic signals by pedestrians, result in unacceptable injury risk to pedestrians and cyclists. To address this problem of travel speeds above 30 km/h through signalised intersections, vertical deflection treatments can be used, with ramp gradients designed specifically to achieve speeds of 30 km/h or less. There are two main options for achieving Safe System speeds.

Raised intersections with 10 or 20 km/h ramps

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓✓	✓

Raised intersections with platforms designed to be traversed at 20 or even 10 km/h, are capable of creating Safe System risk levels for pedestrians and cyclists. These conditions can be achieved with the appropriate degree of vertical deflection. Figure B.9 illustrates this concept at a major roundabout-controlled intersection in the centre of Brussels, Belgium. In addition to the vertical deflection on entry, pedestrians have the benefit of a highlighted cross-walk and a small refuge island to assist in crossing this busy intersection. Given the high traffic volumes, signalisation of the roundabout could reasonably be considered and be expected to aid operation, while retaining the risk reduction benefits of the roundabout geometry. Because cyclists are at elevated risk in multi-lane roundabouts, compared with single lane roundabouts, signalisation would likely improve rider safety as well.

Threshold platforms at intersections

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	

Pedestrians crossing side-streets where they intersect with City Streets are at risk of being struck by turning traffic. In two-way streets, the risks are higher than in one-way streets as more conflict points exists. While only right-turns are permitted from Liverpool Street at its intersection with Criterion Street, there is a significant risk of pedestrians on Liverpool Street coming into conflict with these right-turning vehicles.

This crash type is systemic in busy pedestrian areas, including City Streets. A corresponding form of systemic risk for cyclists involves motorists leaving local side-streets without giving way to approaching cyclists on the City Street. However, in the case of Liverpool Street at its intersection with Criterion Street, this is not relevant due to Criterion Street operating in only one direction, away from Liverpool Street.

The risk of crashes and the severity of any resultant impacts can be moderated by threshold platforms that help to slow turning-vehicles into (or, where applicable, out of) the city side-street. Figure 4.15 shows an example of a threshold platform at an intersection between a City Street and a local street in London. By providing continuity of the footpath level across the intersection, the threshold design not only enhances safety for pedestrians but helps to prioritise pedestrian movements along the City Street. Where there is high pedestrian and/or vehicle volumes, a zebra crossing (with static signing only) can be added to strengthen pedestrian priority. In some instances, it may be both feasible and desirable to close the side-street, thereby eliminating the risk of collisions between turning-vehicles, and pedestrians and cyclists moving along the City Street. Amenity of the City Street and surrounding streets should also be improved.

Figure 4.15: Example of intersection threshold treatment in Covent Garden, London

Between intersections – sharing space

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓✓

Sharing spaces between motorists and pedestrians in City Streets is not common practice in Australasia but use and interests appear to be growing. The primary elements of sharing space in Australasia, leading to alignment with Safe System risk levels, are the low speed limits (typically 10 km/h) and the creation of a physical setting that makes low travel speeds the natural choice. Figure 4.16 shows how space is shared in a town square in Norrköping in Sweden, where pedestrian activity and cycling movements are constant and high at certain times of the day. In Australasia, the shared zone concept requires vehicle speeds of 10 km/h or lower and drivers to give way to pedestrians. Such designs support locations with high Place values and facilitate provision of public seating, and the planting of vegetation and other street features to enhance the amenity and visual appeal of the area.

In shared zones, vehicle access is still permitted but efficient flow is not important for traffic engineers. As with all M&P families, access must be provided for emergency services, as well as for general service and construction vehicles. A key aspect of providing good access for service and emergency vehicles is to avoid compromising design forms to accommodate the largest vehicles, when smaller vehicles may meet the local need and allow multiple objectives of a particular M&P family to be met, especially where place is high.

Figure 4.16: Sharing space in a town square in Skvallertorget, Norrköping, Sweden

Source: Tyréns, 2014.

Kerb blisters or road narrowing

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓	✓✓	✓

Reducing the width of roadway to be crossed by pedestrians reduces the time spent by the pedestrian exposed to direct crash risk. Further, the narrower roadway makes gap selection safer, especially when the traffic approaches from one direction only and the speed limit is 30 km/h. The example shown for a city street in London (Figure 4.17) illustrates this form of design, with safety platforms also integrated within the design. This combination of features is considered to be aligned with Safe System risk levels. In this particular case, parking is allowed close to the crossing location, which tends to restrict sight lines between approaching motorists and crossing pedestrians. However, the low travel speeds elicited by this treatment help to overcome risks due to limited sight lines. In situations where children are crossing, such as at schools or near playgrounds in Local Streets, extended sight lines are desirable to overcome added risks due to their shorter stature and their less predictable behaviour.

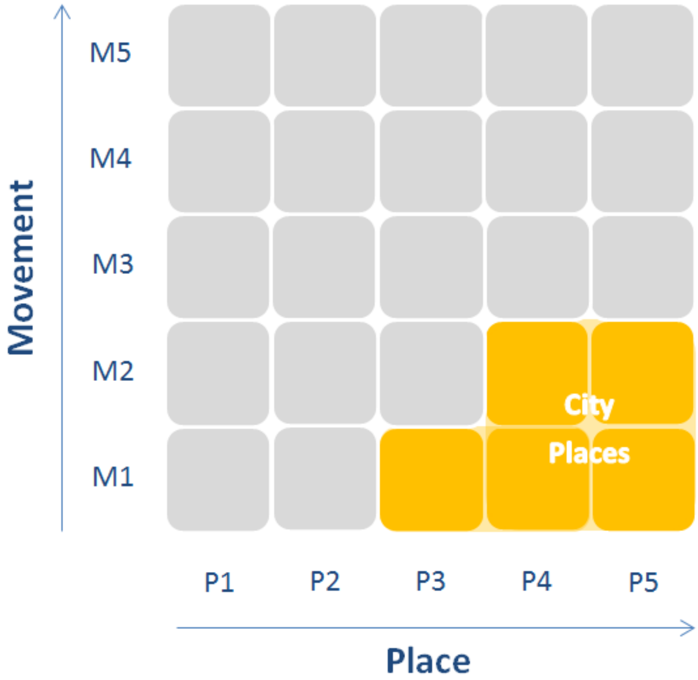
Figure 4.17: Kerb blisters with safety platforms in a 20 mph city street in London

4.4 City Places

4.4.1 General Description

City Places are roads and streets with high demand for pedestrian activities and lower levels of vehicle movement. City Places are places communities value and for people and visitors to enjoy (DoT 2019).

Figure 4.18: City Places on the Movement and Place Framework



4.4.2 Key Movements in City Places

The key movement considerations in City Places are outlined below. From the of perspective a vulnerable road user, the priority is to avoid potentially harmful conflicts between any combinations of modes, but especially between pedestrians and cyclists, and the modes that pose a threat to safety or the value of place.

- Pedestrians: Large numbers of pedestrians visit and spend time in City Places and therefore safe, high-quality walking conditions are a top priority.
- Cyclists: For the same reasons as for pedestrians, cyclists are also a priority mode to access City Places. However, once they have reached their destinations, care must be taken as to how they move safely around in City Places, both for their safety, and for the safety and enjoyment of pedestrians and others.
- Public Transport: high-quality public transport connections are needed to and from City Places. Good connections and services provide the necessary support for pedestrian and cyclist access to City Places.
- General traffic: would normally be afforded low priority, consistent with the low movement value that applies in City Places. Where needed, access may be provided at low risk vehicle speeds.
- Freight: other than to provide adequate access for basic services (e.g., goods delivery, construction, waste-disposal and emergency services vehicles), freight would not receive high priority in City Places. Designing to accommodate the larger vehicles of the types that need access requires careful assessment if meeting the place value will be compromised as a result.
- Other: motorcyclists could be expected in significant numbers in City Places, given the prevailing types of land use. With the main priority assigned to the safe and convenient movement of pedestrians and, under appropriate conditions, cyclists, access by motorcyclists and users of small personal mobility devices will need careful consideration to avoid conflict and to protect the high place value of City Places.

In summary, the focus of measures in City Places will be on high-quality surroundings that prioritise walking, cycling and essential access rather than the movement of general traffic, motorcyclists and freight.

4.4.3 Key Places in City Places

The key place features of City Places are outlined below. Demand is likely to be spread across the day and week, with peaks concentrated around business hours, evenings and on weekends.

- Places of employment – City Places are likely to be places of substantial employment, potentially across a diverse range of types and professions.
- Entertainment, retail and restaurant precincts – will be predominant features of City Places and major attractors and generators of pedestrian movement.
- Recreation facilities and open spaces – are characteristic features of City Places, with parks and public realm spaces providing opportunities for large number of people to gather for enjoyment, exercise and the company of others.
- Special event venues such as sporting stadiums – increasingly, large, multi-purpose sporting stadia and venues are being constructed in big cities and are being accompanied by entertainment and dining facilities. These public facilities require high quality walking and cycling facilities, with strictly limited access of general traffic for their success.
- Major transport interchanges – with the land uses found and emerging in City Places, and the high and potentially intense levels of activity described above, high capacity, high-quality public transport services are required for such areas. Continuing dependence on private car travel to and from City Places will become increasingly unsustainable as cities grow, and will set up cities for long-term liveability problems.

4.4.4 Safe System Measures for Pedestrians and Cyclists in City Places

Table 4.3: City Places – Summary of Safe System aligned pedestrian and cyclist measures

Safe System treatment	Indicative cost
At intersections in City Places	
Threshold platforms at intersections	$
All-way stop signs	$
Restricted access intersection	$$
Safety platforms (30 km/h or lower) on all approaches	$$
Geo-fencing technology for public transport, trucks and other large vehicles	$$$
Roundabouts with 20 or 30 km/h wombat crossings	$$$
Raised intersections with 10 or 20 km/h ramps	$$$
Between intersections in City Places	
30 km/h speed limits or lower	$
Playground zones	$
On-road cycle lanes	$
Wombats in 30 km/h (or lower) speed zones	$$
Limit access by mode	$$
Kerb blisters/road narrowing (30 km/h setting)	$$
Speed platforms (30 km/h)	$$
Horizontal deflection	$$
Textured or coloured pavements (30 km/h speed limits)	$$
Car-free streets (potentially time-based)	$$$
General road narrowing (30 km/h setting)	$$$
Full segregated cycle paths	$$$
Shared space (with raised textured pavements and 10 km/h speed limits)	$$$$
Pedestrian malls	$$$$

Some of these measures are described more fully following the stereotypical case and, where feasible, illustrated with photographs or other image types. All treatments are covered in more depth in Appendix B.

In City Places, Safe System-aligned measures that are conducive to the inclusion of place-making features should be prioritised, provided safety is not compromised. Seating, public art, trees and other landscaping, shade and shelter, alternative forms of paving and functional features such as bicycle parking can be included. The aggregate effect of these place-making features is to strengthen the sense of Place. In turn, a stronger sense of Place, including through the use of priority Safe System-aligned treatments, raises the driver expectations of encountering pedestrians and cyclists, which can be expected to lead to a reduction in the potential for conflict. Well-designed facilities that are safe and convenient will also attract greater use.

A Stereotypical Case – Wynyard Quarter, Auckland, NZ

City Places are characterised by having generally low through movement requirements but very high place values. They exist as destinations in their own right, mainly because they contain land uses that attract citizens, often across a wide age-range, and where there is no strong need for the movement of general traffic through the area. Access to and from a City Place, in the form of an efficient public transport system, and safe walking and/or cycling, are usually high priorities. Once there, visitors to the City Place will generally wish to spend time enjoying the location. Creating aesthetic and vibrant surroundings therefore assumes a high priority.

A case study has been selected from Auckland NZ to highlight the features of a City Place that are evolving quite rapidly. The area, which is known as Wynyard Quarter, is extensive (37 hectares) and located on Auckland's waterfront, immediately adjacent to the city centre. The area is being reclaimed from its former use as part of Auckland's marine and fishing industries, to be used progressively for a variety of purposes, such as a high-tech industries, apartments, a major marine centre, communal vegetable gardens, restaurants, cafés and bars, playgrounds, a theatre, a five-star hotel and potentially numerous other uses still to be defined.

Figure 4.19 shows the overall area in relation to the Auckland central city. This area was chosen because it is still in the early stages of redevelopment and, while there are some examples of good practice in providing for pedestrians and cyclists already in place, some opportunities to consider ideas generated as part of this report may also arise.

The Wynyard Quarter is bounded on three sides by Auckland Harbour, providing natural protection from the adverse of effects of significant through-movement of general traffic and freight. The high concentration of a wide variety of land uses – businesses, residential, entertainment and dining establishments, industries, community and recreational activities – determines that the key movement requirements are to provide and facilitate low risk and convenient movement of the active modes throughout the development, and to provide access to the area to motorised traffic with a destination within.

With this context, it is immediately clear that low travel speeds for all motorised vehicles are a priority. Good connections to public transport services at the perimeter of Wynyard Quarter will also be important, as will good connectivity to surrounding City Streets and Hubs, and Movement Corridors and Connectors.

Looking ahead, there is potential to operate small autonomous vehicles at low speed around Wynyard Quarter to enable delivery of goods during the hours of low exposure of pedestrians and cyclists (e.g., midnight to 5am). These vehicles could also be used to bring people into and out of the site, to access, for example, apartments and hotel accommodation, theatres, etc. The value of this type of approach would be to reduce to a minimum the need for motor vehicles within Wynyard Quarter. Other options to transport people in and out of the City Place, without the use of private vehicles, is to provide an appropriately-scaled light rail service for a long term sustainable development.

Figure 4.19: Google satellite image of Wynyard Quarter, Auckland New Zealand

(downloaded 2 August 2019)

Pedestrian and cycling movements

To deliver Safe System aligned measures for pedestrians and cyclists in City Places, it is desirable to create low speed settings and minimise exposure to vehicular traffic, while also providing safe and convenient access to and from public transport and off-street parking.

Safe and convenient access for general traffic is also required but priority for minimising travel times will be of lesser importance compared with priority for walking and cycling. In such a relatively small area forming this City Place, the impact of low speed on travel times will be negligible in the context of normal journey times. Another desired attribute of City Places is the creation of attractive, highly walkable surroundings. Not only are these qualities much-valued by visitors and residents of Wynyard Quarter but they support commercial viability and property values of the development.

In this M&P setting, pedestrians, cyclists, public transport (buses and taxis) and interchanges are prioritised. Treatments for pedestrians and cyclists are presented in terms of their alignment with Safe System principles or their potential to serve as a supporting treatment or one that can make a worthwhile contribution to pedestrian and/or cyclist safety. Measures are grouped according to their application at intersections or along roads and streets between intersections.

4.4.5 Safe System Priority Treatments

To avoid death to or serious injury being sustained by a pedestrian or cyclist negotiating an intersection, it is fundamentally important that vehicle travel speeds do not exceed 30 km/h. If this can be achieved, together with a low risk of a crash occurring, Safe System risk levels will have been achieved for these two highly vulnerable and rapidly growing road user groups.

Speed limit setting

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

There appears to be strong and growing consensus among road safety professionals that 30 km/h is the appropriate Safe System travel speed for pedestrians (and cyclists). At impacts above 30 km/h, pedestrian (or cyclist) survivability diminishes rapidly. A 30 km/h speed limit has already been applied for streets entering Wynyard Quarter, as shown in Figure 4.20. The speed limit signing is supplemented with the numerals “30” marked on the pavement on entry to each of the local streets serving Wynyard Quarter. This speed limit establishes the base conditions for designing infrastructure to meet Safe System conditions for pedestrians and cyclist. A 30 km/h speed limit also allows riders to share the general traffic lane at low risk. In areas of more intense pedestrian and/or cycling activity, 10 or 20 km/h speed limits should be considered. Exposure reduction is not the primary mechanism for improving safety, however, in some settings lower speed limits will contribute to reduced exposure if motorists choose routes permitting higher travel speeds.

Figure 4.20: 30 km/h speed limit upon entering Wynyard Quarter, Auckland, New Zealand

At intersections – roundabouts with 20 or 30 km/h wombat crossings

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓✓	✓

Urban roundabouts are Safe System aligned for vulnerable road users, provided they incorporate design features specifically for pedestrian and cyclist safety. Figure 4.21 shows an urban roundabout designed specifically to accommodate pedestrians and cyclists at low risk. Preliminary assessment suggests this design form is effective, though a full evaluation was incomplete at the time of finalising this report.

Figure 4.21: 40 km/h speed limit and cyclists and pedestrian protected roundabout design in the Melbourne suburb of South Melbourne

Raised intersections with 20 or 30 km/h platforms

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Raised intersections, with vertical profiles to encourage vehicle speeds of not more than 30 km/h, potentially lower, are suited to City Places. Figure 4.22 shows a design from a new urban area on the outskirts of Stockholm, Sweden. The combination of pavers to provide a contrasting colour to the surface within the intersection, the use of a circular outer kerb line and the raised nature of the intersection create conditions for slow speeds and cautious behaviour by drivers. This design form interfaces well with the approach to the intersection where the footpaths have been widened and the roadway narrowed such as to limit the approach traffic to a single lane. Together, these features are conducive to slow speeds and supportive of the value of place in City Places. The primary mechanisms for improving safety are through reductions in crash likelihood and injury severity, while exposure vehicle may remain unchanged or, or fall marginally.

Figure 4.22: 30 km/h speed limit in combination with textured surfacing and single lane approaches suburb of Hammarby Sjöstad, Stockholm

Between intersections – pedestrian malls

Injury Severity	Crash Likelihood	Exposure to Conflicts
		✓✓✓

The heavy emphasis on walking and the relatively low priority for general traffic, in combination with the types of land use in City Places, make pedestrian malls a good option for creating low risk conditions for pedestrians. They also support the profile of land uses found in City Places, as is evident in Figure 4.23, below, and create pleasant, if not vibrant settings that attract visitors to an urban area. Other active modes, such as cycling, skateboarding and scootering can also be conducted at lower risk in pedestrian malls, given that the environment is car-free, but are not recommended for the safety of pedestrians and others. The riding of bikes, skateboards and scooters is not entirely compatible with City Places and will likely detract from the amenity, walkability and safety of the mall. While avoiding the creation of tripping hazards, selective use of coarse surfaces may help to discourage or slow some incompatible types of device.

Figure 4.23: Pedestrian Mall in Cuba Street, Wellington New Zealand

Shared zones

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓✓

Shared zones are well-suited to City Places because they give priority to pedestrians, which supports the active modes of transport, while still allowing access for general traffic, but under a different set of priorities. Instead of assigning priority to general traffic, regardless of the value of Place, shared zones operate under the explicit assumption that drivers must share the space with other road users, especially pedestrians, rather than enjoy the benefits of road traffic rules that assign priority to the motor vehicle by default. Shared zones align with Safe System risk levels, largely because of the low speed environment, created through good design, and supported legislatively by a 10 km/h speed limit. Shared zones aim to create physical surroundings that make low travel speeds the natural choice of drivers. Figure 4.24 shows a shared zone in the city centre of Auckland. The combination of tree plantings, street surfaces paved at a consistent level between buildings, and the lack of a clear straight path for vehicles help to achieve the intended result.

While also beneficial for cyclist safety, shared zones in City Places are unsuited to fast-riding when pedestrian activity is significant. At these times, cyclists, as well as scooter-riders and skateboarders, would ideally dismount to avoid injury risk among other vulnerable road users and frustration to pedestrians having to be ever-vigilant in the shared zone for the possibility of being hit by fast-moving cyclists.

Figure 4.24: Shared zone Auckland, New Zealand

Footpath widening and road narrowing

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓	✓✓	✓✓

In a 30 km/h environment, roads and streets that have had their footpaths widened and, as a consequence their roadways narrowed to not more than a lane in each direction can be regarded as having been designed for Safe System outcomes, including for pedestrians and cyclists. Some streets in Wynyard Quarter have already been treated in this fashion, as is shown below in Figure 4.25. Under this design configuration, vehicle speeds will generally be low, and the widths of road to cross will be narrower and much simpler in terms of safe gap choice by pedestrians. Cyclists will be able to share general traffic lanes at low risk. While less of a safety consideration, the wider footpaths create space for large numbers of pedestrians, particularly during high-attendance events, and so help to affirm the significance of walking as a transport mode and as a recreational activity in City Places.

Figure 4.25: Footpath widening/road narrowing in Wynyard Quarter, Auckland, New Zealand

Zebra crossings in 30 km/h setting

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓	✓

Zebra Crossings in a 50 km/h or higher speed limit (Australasia's urban default speed limit) is not Safe System-aligned, primarily because a driver who fails to give way to a crossing pedestrian would likely collide at a speed beyond the boundary condition for the unprotected pedestrian (or cyclist). However, when provided in combination with a 30 km/h speed limit and, potentially, kerb outstands, Safe System alignment of the design is achieved. Figure 4.26 shows an example of such a treatment in Wynyard Quarter. A zebra crossing in a 30 km/h setting may dissuade some motorists from using the area unless it is essential for gaining access. Fewer vehicles result in reduced exposure to the potential for pedestrian-vehicle conflicts.

Figure 4.26: Daldy Street entry to Wynyard Quarter, Auckland

4.5 Activity Streets and Boulevards

4.5.1 General Description

Successful Activity Streets and Boulevards provide access to shops and services by all modes. There is high demand for movement as well as place with a need to balance different demands within the available road space. Activity Streets and Boulevards aim to ensure a high quality public realm with a strong focus on supporting businesses, traders and neighbourhood life (DoT 2019).

Figure 4.27: Activity Streets and Boulevards on the Movement and Place Framework

4.5.2 Key Movements in Activity Streets and Boulevards

The key movement considerations in Activity Streets and Boulevards are outlined below.

- Pedestrians: Significant numbers will typically be found on Activity Streets and Boulevards, both accessing the activity street or boulevard as a final destination or passing through and across the environment as they travel between destinations and public transport stops.
- Cyclists: Significant and growing numbers, including delivery services to businesses and other properties.
- Public Transport: high quality connections to public transport are needed in Activity Streets to provide access to shops and services by all modes.
- General traffic: Significant numbers, both accessing Activity Streets and Boulevards as a final destination (including taxi and ride-share) and also moving through and across the cities and urban areas. Activity Streets and Boulevards can be classified as having substantial movement value which prove more challenging to resolve when the place value is also high.
- Freight: Significant numbers, delivery drivers and construction/service vehicle.
- Other: Significant numbers of motorcyclists due to extensive parking associated with businesses and traders along the Activity Streets and Boulevards. Small/innovative mobility devices are expected to become increasingly prevalent.

4.5.3 Key Places in Activity Streets and Boulevards

The key place features of Activity Streets and Boulevards are outlined below.

- places of employment
- entertainment, retail, business and restaurant facilities
- community facilities and medical services
- Public realm and other open spaces
- places to walk for enjoyment/recreation
- significant transport interchanges and links to public transport stops.

4.5.4 Safe System Measures for Pedestrians and Cyclists in Activity Streets and Boulevards

This section describes Harbour Drive in Coffs Harbour, NSW, in the context of it representing a commonly encountered type of Activity Street, albeit with its unique features and characteristics. Other examples of Activity Streets and Boulevards can be found in Turner et al., (2017). While this case study illustrates the types of measures that might apply in Activity Streets and Boulevards, their direct practical application has not been thoroughly assessed for Harbour Drive. Rather, the measures discussed have characteristics making them potentially applicable to Activity Streets and Boulevards.

Safe System-aligned measures for pedestrians and cyclists that could be considered for Activity Streets and Boulevards are described below and summarised in Table 4.4.

Table 4.4: Activity Streets and Boulevards – Summary of Safe System aligned pedestrian and cyclist measures

Safe system treatment	Indicative cost
At intersections in Activity Streets and Boulevards	
Signalised intersections with 'Scramble' phasing (30 km/h speed limit)	$$
Geo-fencing technology for buses, trucks and other large vehicles	$$$
Roundabouts with 30 km/h wombat crossings	$$$
Raised intersections with 30 km/h (or lower) ramps	$$$
Signalised roundabout with separate phases for cyclists and pedestrians	$$$
Between intersections in Activity Streets and Boulevards	
30 km/h speed limits or lower	$
Zebras or wombats in 30 km/h (or lower) speed limits	$$
Fully segregated cycle paths	$$$
Medians	$$$
Car-free streets (potentially time-based)	$$$
Pedestrian malls	$$$$
Shared space (with raised textured pavements and 10 km/h speed limits)	$$$$

Some of these measures are described more fully following the stereotypical case and, where feasible, illustrated with photographs or other image types. All treatments are covered in more depth in Appendix B.

A Stereotypical Case – Coffs Harbour

Coffs Harbour is a sizeable provincial city situated on the mid-north coast of New South Wales. With a population of around 70,000 and many natural attractions in the region, Coffs Harbour has a large tourism industry based largely on marine, fishing and other coastal activities. The combination of tourism, a strong agricultural industry, significant commercial activity and the Southern Cross University makes Coffs harbour a busy regional transport hub.

Harbour Drive in Coffs Harbour has a strong place function, running through the main shopping area. There is a range of shops, restaurants and cafes along both sides of the street, with pedestrian demand being highly concentrated during business hours, and extending into the evenings. There is not particular provision existing for the safety of cyclists, other than the 40 km/h speed limit and the shared space speed limit of 10 km/h. There is significant pedestrian movement both along and across the street, as people move between the shops and the adjacent multi-level car park through City Square, off Park Avenue Lane. Harbour Drive also has a moderate movement function as it has important regional road connections at either end and also connects with the Pacific Highway at the Northern end of this section. A Google satellite image, centring on Harbour Drive, is shown in Figure 4.28.

Figure 4.28: Google satellite image of Harbour Drive, Coffs Harbour NSW

(downloaded 28 August 2019)

High-quality walking and cycling facilities, and public transport services, are needed to support the intended and current forms of land use. The movement of private and commercial vehicles through this part of Coffs Harbour is of lower priority relative to the prioritisation of commercial, social and business activities. While delivery and pick up of goods are also fundamental to the viability of the commercial and business activities, movement of this type can be restricted to times of low pedestrian and cyclist activity. Thus, high-priority modes in this Harbour Drive are:

- walking
- destination cycling
- interchange facilities to link shops, restaurants/cafés, offices, etc., with bus and taxi services
- small goods delivery vehicles, limited-scale construction and service vehicles, such as waste removal, and emergency services access (i.e., paramedic, fire-fighting and police vehicles).

Activity Streets may, in the longer term future, need to facilitate the safe movement of small autonomous vehicles, as well as a variety of innovative mobility vehicles and devices currently appearing in the marketplace (e.g., e-scooters/e-bikes and mobility scooters).

Pedestrian, and cycling movements

To deliver Safe System-aligned measures for pedestrians and cyclists in Activity Streets and Boulevards, it is desirable to create low speed settings and minimise exposure to vehicular traffic, while also providing safe and convenient access to and from bus services and off-street parking. The main reduction in risks for pedestrians and for cyclists using Harbour Drive come from the speed limit reduction to 40 km/h compared with the default of 50 km/h. In addition, speeds have been further moderated by the shared space speed limit of 10 km/h, where the highest concentration of pedestrian crossing activity occurs. Differential speeds between motorists and cyclists are reduced and the speed at impact in crashes that do occur will tend to be lower and therefore less severe. Harbour Drive has been designed with pavement surfaces that extend across the full width of the roadway at footpath level to offer Safe System risk levels, when accompanied by approach ramps that elicit 30 km/h travel speeds or lower. These forms of treatment can be usefully provided to promote or support existing high levels of pedestrian crossing activity within an Activity Street (or Boulevard). Figure 4.29 illustrates the shared space treatment in Harbour Drive, Coffs Harbour, which includes a 10 km/h speed limit and textured surfacing.

Figure 4.29: Shared space and shade sails combine to moderate speeds where pedestrian crossing activity is most concentrated (Coffs Harbour, New South Wales)

While it is also important to provide safe and reliable access for general traffic, minimising travel times is of lower priority relative to the importance of place. The evidence on the role of travel speeds on crash and injury risk is indisputable and especially influential for pedestrians, cyclists, motorcyclists and other unprotected road users. Any impact on travel times will be minimal in the context of normal journeys. Another desired attribute of Activity Streets and Boulevards is the creation of attractive surroundings. Not only are these qualities much-valued by shoppers and visitors but amenity improvements support commercial viability and property values.

In this M&P setting, pedestrians, cyclists, public transport (buses and taxis) and interchanges are prioritised. Treatments for pedestrians and cyclists are presented in terms of their alignment with Safe System principles or their potential to serve as a supporting treatment or one that can make a worthwhile contribution to pedestrian and/or cyclist safety. Measures are grouped according to their application at intersections or along roads and streets between intersections.

4.5.5 Safe System Priority Treatments

To avoid death to or serious injury being sustained by a pedestrian or cyclist negotiating an intersection, it is fundamentally important that vehicle travel speeds do not exceed 30 km/h. If this can be achieved, together with a low risk of a crash occurring, Safe System risk levels will have been achieved for these two highly vulnerable and rapidly growing road user groups.

Speed limit setting

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Based on the various pedestrian fatality risk relationships with impact speed, a 30 km/h speed limit is generally accepted as aligning with Safe System principles. A 40 km/h speed limit has been applied along Harbour Drive, in the form of a “High Pedestrian Activity” Area, as shown in Figure 4.30. The speed limit is supplemented with the numerals “40” marked on the pavement on entry to the street. While 40 km/h creates much lower risks for pedestrians and cyclists than 50 or 60 km/h, 30 km/h is more compatible with Safe System principles. Specifically, pedestrians struck at 40 km/h have a 2-3 times greater risk of death than if struck at 30 km/h. A 30 km/h speed limit also reduces the crash and injury risk for cyclists, and allows riders to use the vehicle lane at low risk. In some instances, motorists may choose alternative routes in response to a perception of low mobility for general traffic or freight. This may lead to minor reductions in exposure.

Figure 4.30: Harbour Drive 40 km/h area speed limit (High Pedestrian Activity area)

At intersections

To assure Safe System conditions for pedestrians and cyclists at intersections, vehicle speeds should not exceed 30 km/h. When achieved, together with minimising crash risk, all vulnerable road users should be able to negotiate intersections with a high chance of avoiding a crash and of surviving any potential collision.

Roundabouts exist at nearby Harbour Drive and Earl Street, and at West High Street and Mooree Street. However, the major intersections at either end of Harbour Drive, over the section defined as an Activity Street, are controlled by traffic signals (at Gordon Street and at the Pacific Highway). Intersection signals, designed and operated in their standard form, are not Safe System aligned; left and right-turning vehicles are often in conflict with pedestrians crossing on a walk signal (unless separate vehicle turn phases operate), and red light running by drivers and/or non-compliance by pedestrians may lead to collisions at impact speeds well above the human tolerance to severe injury. To achieve Safe System risk levels for pedestrians crossing at major intersections, alternative design forms are needed.

Roundabouts with wombat crossings (platforms 30 km/h maximum)

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓✓	✓

Roundabouts with wombat crossings to cater for pedestrian movements can deliver the safety improvements required to achieve Safe System risk levels for all road users. An example from the City of Bayside in Victoria is shown in Figure 4.31.

Figure 4.31: Roundabout with wombat crossings to cater for pedestrian movements – City of Bayside, Victoria

Signalised roundabouts with separate phases for cyclists and pedestrians

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓✓	

Roundabouts are excellent at achieving low injury risk levels for vehicle occupants. However, in their standard form, they provide modest facilities for pedestrians and cyclists. Additional measures are needed. Signalised control of roundabouts allows the safety benefits of lower travel speeds, more favourable conflict angles and a vast reduction in the number of conflict points within the intersection to be realised. While not common, this design form can offer many advantages at key intersections along Activity Streets and Boulevards, including the opportunity to directly control the green time to each user group. Roundabouts and their approach islands can be landscaped to improve visual amenity in Activity Streets and Boulevards.

Between intersections

Zebra crossings (with 30 km/h speed limit)

Injury Severity	Crash Likelihood	Exposure to conflicts
✓✓	✓✓	✓

A zebra crossing is situated along the commercial section of Harbour Drive. Its safety performance is enhanced by kerb blisters to help ensure good sight lines between drivers and pedestrians, and to reduce the time spent by pedestrians exposed to crash risk while crossing the roadway. A zebra crossing located in a 40 km/h area speed limit can be transformed to meet Safe System performance with the addition of a 30 km/h safety platform. With a safety platform, a zebra crossing becomes a wombat crossing and takes on a substantially lower fatal or serious injury risk profile (around 70% lower).

Figure 4.32 shows the potential to include public seating, street plantings and cycle parking into the space created by kerb blisters or outstands. This clearly adds to the quality of place as well as delivering safety and convenience for pedestrians.

Figure 4.32: Kerb blisters and zebra crossing (including provision for seating, cycle parking and street beautification)

Medians (with 30 km/h speed limit)

Injury Severity	Crash Likelihood	Exposure to conflicts
✓	✓✓	

In busy Activity Streets and Boulevards, medians (and pedestrian refuges) can be constructed to assist pedestrians to simplify the gap selection task by breaking their crossing manoeuvre into two stages; while not appreciably affecting exposure (i.e., numbers of pedestrians and cyclists in potential conflict), a median allows pedestrians to wait safely for a safe gap in the second direction of traffic. As can be seen in Figure 4.33, medians can also add visual appeal to an Activity Street or Boulevard, by allowing street-tree planting and other vegetation, and creating space for public seating and other features to enhance the functionality and appeal of the surroundings. The planting of street trees and other vegetation should not compromise safe sight lines; this can gradually become problematic as vegetation matures.

Such enhancements encourage people to enjoy the 'place' aspect of the street (Figure 4.33 illustrates the provision of bicycle parking within the median), as well as the shopping, dining and entertainment services in the area. Where there are clear concentrations of pedestrian crossing movements, zebra or wombat crossings can be integrated within the overall median design. In a 30 km/h environment, medians provide Safe System risk levels for pedestrians crossing streets between formal crossing facilities.

Figure 4.33: Medians support safer pedestrian crossing throughout the length of an Activity Street, not just at specific locations (note scope for bicycle parking)

Separated cycle facility

Injury Severity	Crash Likelihood	Exposure to Conflicts
	✓✓✓	

An alternative to bicycle lanes with an adequate lateral clearance distance to parked cars or riding on the road (i.e., sharing the general traffic lane) is to provide separated cycle facilities. These may require the removal of on-street parking or, where space permits, allow the provision of on-street parking between the separated cycle facility and the general traffic lanes. This arrangement offers protection to riders from passing traffic. Figure 4.34 illustrates the use of separated cycle facilities in Stockholm (helmet wearing is compulsory in Sweden only for children under 15 years of age).

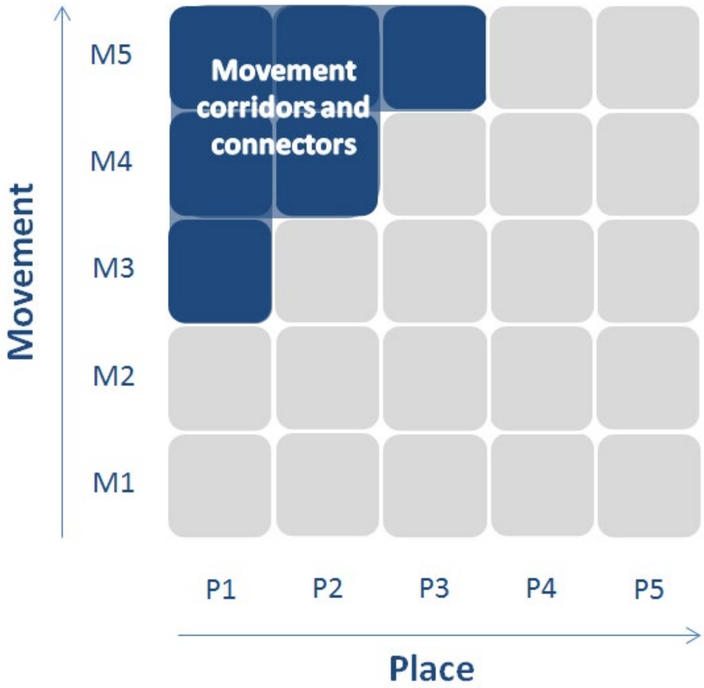
Figure 4.34: Separated footpath with parking between cyclists and general traffic Sturgatan, Stockholm

4.6 Movement Corridors and Connectors

4.6.1 General Description

Successful Connectors should provide safe, reliable and efficient movement of people and goods between regions and strategic centres and mitigate the impact on adjacent communities (DoT 2019).

Figure 4.35: Movement Corridors and Connectors on the Movement and Place Framework



4.6.2 Key Movements in Movement Corridors and Connectors

The key movement considerations in Movement Corridors and Connectors are outlined below.

- Pedestrians: It is likely that the need for pedestrians to move along and across Movement Corridors and Connectors will be substantial in urban areas and potentially high on roads with a medium-level place value. A high focus on the movement of general traffic and freight does not preclude a substantial, if not strong, need for people to move about on foot. Providing high priority for pedestrians along Movement Corridors and Connectors will be more difficult when the place value is also high.
- Cyclists: As with pedestrians, cyclists often rely on the use of busy road, either to cross or to ride longer distances for more significant journeys, such as commuting or for recreational and/or training rides.
- Public Transport: the major forms of on-road public transport, namely buses and, in some jurisdictions, light rail and trams, operate along or cross Movement Corridors and Connectors. This necessarily leads to significant levels of pedestrian activity both along and across these major traffic routes.
- General traffic: Movement Corridors and Connectors represent the major form of movement of general traffic travelling over significant distances.
- Freight: As with other motorised vehicle modes, Movement Corridors and Connectors play a vital role in transferring freight between cities and towns, as well as across metropolitan areas. While freight is confined wherever possible to the use of routes best-suited for this purpose, today's road transport network requires a substantial part of the freight task being transported along roads and through areas with significant, if not important, place values.
- Other: Movement Corridors and Connectors serve a diverse array of other forms of movement, such as motorcyclists, tourists and taxis/hire cars.

Along Movement Corridors and Connectors, levels of service for vulnerable road users may vary by time-of-day and day-of-week, for example, during high commuting times. During these periods, on-road parking could be restricted to provide more space for cyclists, when exposure to crash risk is elevated. On-street parking can be a significant contributor to crash risk for cyclists, with 'car-dooring' of riders and conflict with vehicles entering or leaving on-street parking bays being among the most common problems. On-street parking is often a major constraint when a reallocation of corridor space is needed to safely accommodate cyclists. Similarly, the level of service offered to pedestrians is often restricted during peak traffic periods, when traffic signal timings and phasing strongly favour general traffic, freight, and sometimes public transport.

4.6.3 Key Places in Movement Corridors and Connectors

Movement Corridors and Connectors pass through places of all types and values, especially in the metropolitan cities of Australasia. The key place features of Movement Corridors and Connectors are:

- Outer metropolitan suburbs that can include industrial and residential areas, transitioning into agricultural uses as roads extend further from city centres.
- Inner metropolitan areas, where population densities are high and business, educational, commercial and residential activities operate at substantial, if not intense, levels.
- A major characteristic of Movement Corridors and Connectors is that they often pass through areas of low place value, including rural areas where pedestrian activity is low, other than in provincial cities, towns and small settlements situated en route. As well as pedestrian activity in these urban or semi urban areas, there will also be cyclists. Cyclists riding long distances along Movement Corridors and Connectors, while relatively few, should not be overlooked in the planning and management of safety and movement along these major routes.
- In Australasia's major cities, Movement Corridors and Connectors can interface with the full array of urban land uses and a wide array of place values.

4.6.4 Safe System Measures for Pedestrians and Cyclists on Movement Corridors and Connectors

The provision of Safe System aligned measures for pedestrians and cyclists along Movement Corridors and Connectors will, ideally, focus on effective separation, with some speed management where separation is not, in itself, adequate. Based on the above, potential Safe System-aligned measures for pedestrians and cyclists for Movement Corridors and Connectors are described below and summarised in Table 4.5.

Table 4.5: Movement Corridors and Connectors – Summary of Safe System-aligned pedestrian and cyclist measures

Safe System treatment	Indicative cost
At intersections in Movement Corridors and Connectors	
Threshold platforms at intersections with side streets	$
Intersection signals with 30 km/h platforms or with 30 km/h speed limit	$$$
Signalised 'tennis ball' intersections	$$$$
Roundabouts with Wombats (30 km/h platforms)	$$$$
Signalised roundabout with exclusive phases for cyclists and pedestrians	$$$$
Between intersections in Movement Corridors and Connectors	
Speed limit setting	$
Pedestrian operated signals with safety platforms	$$$
Grade-separation of pedestrians and cyclists from vehicular traffic	$$$$
Segregated Cycle Paths	$$$$
On-road protected cycleway with physical barrier	$$$$

Some of these measures are described more fully following the stereotypical case and, where feasible, illustrated with photographs or other image types. All treatments are covered in more depth in Appendix B.

A stereotypical case – Warrigal Road, suburban Melbourne

Warrigal Road in suburban Melbourne is a major north-south arterial that serves a high movement function throughout a typical weekday, and continues to perform this role on weekends and well into the night. As well as carrying medium to high volumes of general traffic for around 18 hours per day, it is a major bus route which connects the western with the south-eastern suburbs of Melbourne. In performing this important public transport function, it connects buses with a number of Melbourne's busy rail and tram services, and with schools and shopping centres, including the major regional complex, Chadstone Shopping Centre. Warrigal Road also carries substantial commuter and recreational cycling volumes, despite its lack of safe clearance between riders and passing motor traffic.

Figure 4.36: Warrigal Road – a Movement Corridor and Connector, where bus services attract pedestrians

The speed limit is 60 km/h over the predominantly undivided sections, which carry two relatively narrow lanes of traffic in both directions. Some sections of this Movement Corridor and Connector are divided and operate at either 60 or 70 km/h. There are numerous signalised intersections along its 19 km length. Warrigal Road is used by both general and freight traffic to access the M1 Freeway, the Princes Highway and various other major metropolitan east-west routes. The road passes through a variety of land uses, including residential, sporting, light industrial, shopping, schools, churches and local businesses. Some sections have part-time 40 km/h speed limits (operating from 8am to 8pm daily), with red light and speed cameras to enforce compliance at a signalised intersection situated within a busy pedestrian activity section.

Pedestrian and cycling movements

Given the status of Warrigal Road as a Movement Corridor and Connector and having the characteristics described above, the following modes should receive priority:

- general traffic
- freight
- buses and interchanges with other public transport
- pedestrians
- cyclists.

In this M&P setting, general traffic, freight, pedestrians, cyclists, buses and interchanges are prioritised. Treatments for pedestrians and cyclists are presented in terms of their alignment with Safe System principles or their potential to serve as a supporting treatment or one that can make a worthwhile contribution to pedestrian and/or cyclist safety. Measures are grouped according to their application at intersections or along Movement Corridors and Connectors between intersections.

The intersections of Movement Corridors and Connectors with other Movement Corridors and Connectors present safety problems for cyclists and pedestrians. These types of intersections tend to be wide and require pedestrians to negotiate multiple traffic lanes, carrying large number of vehicles travelling at high speeds (e.g., 60, 70 or 80 km/h). Cycle times are typically much longer than pedestrians wish to experience, which leads to unacceptable levels of compliance with walk signals. Poor pedestrian compliance, combined with red light running, often at speeds far above the Safe System biomechanically derived boundary condition of 30 km/h for pedestrians and cyclists results in high risk environments.

Figure 4.37 shows a typical example of a major intersection of two Movement Corridors and Connectors, one being Warrigal Road. It is also evident from this example that pedestrians are exposed to high travel speeds, including where vehicles are negotiating free-flowing slip lanes. In these circumstances, drivers tend to have their heads turned to the right (away from pedestrians) to pick a safe gap in conflicting traffic. Motorists are commonly involved in right-turn-against crashes at traffic signals (Triggs, 1980), unless fully-controlled-right-turn phases are provided. This crash type is also systemic for cyclists; in this configuration of road users, the cyclist is invariably travelling straight ahead and the motorist turning right. These crash types are systemic at intersection signals and particularly threatening at large, high-exposure intersections where the impact speeds are far above Safe System levels.

Figure 4.37: Warrigal Road signalised intersection where two Movement Corridor and Connector cross

4.6.5 Safe System Priority Treatments

To avoid death or serious injury being sustained by a pedestrian or cyclist negotiating an intersection, it is fundamentally important that vehicle travel speeds do not exceed 30 km/h. If this can be achieved, together with a low risk of a crash occurring, Safe System risk levels will have been achieved for these two highly vulnerable and rapidly growing road user groups.

Speed limit setting

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	

Setting the speed limit along Movement Corridors and Connectors will strongly influence the type, design and placement of infrastructure needed along a route intended to perform a high movement function.

Travel speeds are the primary determinant of crash and injury risk. The importance of speed to pedestrian and cyclist safety is even more pronounced. Long-term trends in pedestrian fatalities in Victoria showed a dramatic drop in the incidence of pedestrian fatalities immediately after the introduction of enforcement of existing speed limits. Pedestrian fatalities fell from 160 per annum in 1989 to just 93 per annum in 1990. This unprecedented drop in annual fatalities occurred in a single year and continued to trend downwards after 1990. The size of the effect suggests that an even greater reduction could occur if speed limits were set explicitly to consider pedestrian and cyclist vulnerability in traffic. Section 3.1.1 describes the results of other research that quantifies the powerful relationship between pedestrian fatality risk and travel speed.

At present, speed limits along Movement Corridors and Connectors are set with a primary focus on the mobility of general traffic and freight. While the speed limit on urban roads of this type has commonly been set above the urban default speed limit of 50 km/h in order to achieve higher levels of mobility, these classes of road, particularly in metropolitan settings, often experience average speeds in peak conditions that are well below the speed limit, due largely to heavy congestion and the need to stop/queue at traffic signals. There is also an emerging view, backed by observational data, that on some high movement roads, vehicle throughput can be increased by lowering travel speeds so that they are better matched to the capacity of the road in peak conditions. The theory is analogous to the use of ramp metering signals on freeways to promote smooth and efficient traffic flow, with minimal disturbance to the optimal flow of traffic caused by high levels of unproductive acceleration and, hence, braking.

It is recommended both for the safety of pedestrians and cyclists, and the efficient flow of traffic on high movement function roads, that consideration be given to reducing speed limits to optimise route performance. Adoption of default urban speed limits along undivided urban Movement Corridors and Connectors may well result in safer, more efficient flow. However, further analysis and understanding of the effects of this approach are needed before the widespread adoption of such an approach.

In Australia, urban Movement Corridors and Connectors, on which the major proportion of total exposure to death of serious injury risk to pedestrians and cyclists occurs, typically have speed limits spanning the range of 60, 70 and 80 km/h. Speed limits of 90 and 100 km/h, where pedestrians cross and cyclists ride are, thankfully, rare. By contrast, the 50 km/h urban default speed limit is more widely used on Movement Corridors and Connectors in NZ. This decision in NZ has, undoubtedly, prevented a substantial amount of pedestrian and cyclist trauma on the country’s urban roads. McLean (2008) found that, had the default urban speed limit of 50 km/h been adopted instead of 60 km/h when imperial units were being converted to metric units in 1974, over 2,700 fewer pedestrian lives would have been lost in Australia over the ensuing quarter of a century. This corresponds to around 20,000-25,000 fewer serious injuries to pedestrians as well. Thus, from the perspective of the safety of pedestrians and cyclists, lower travel speeds are essential if effective separation cannot be achieved.

Until the speed limit has been set for any given Movement Corridor and Connector, it is difficult to determine the infrastructure measures needed to provide Safe System risk levels for pedestrians and cyclists. For progress to be made with this project, it will be assumed that speed limits above the urban default will continue to be set in the future. These speeds are vastly beyond the biomechanical tolerance of humans to injury unless they have the protection of a vehicle structure. At these impact speeds, the survivability is low for a pedestrian or cyclist. Thus, it is essential to focus on separation as the main means of providing safety for vulnerable road users. It is considered unlikely that motorists will, on a significant scale, choose alternative routes in response to a perception of low mobility for general traffic or freight on Movement Corridors and Connector roads. Trials and robust evaluations would be needed to identify exposure effects.

At intersections – signalised intersections with 50 km/h platforms

Injury Severity	Crash Likelihood	Exposure to conflicts
✓✓	✓✓	

Intersection signals cannot be regarded as aligned with Safe System principles when designed and operated in their conventional form. This is because pedestrians are not always compliant with pedestrian signals and red light running occurs at speeds that exceed the crashworthiness of the struck vehicle and, in the case of pedestrians and cyclists, far above the 30 km/h biomechanical tolerance limits that define Safe System risk levels. It is also common for pedestrians to be struck by right- or left-turning traffic, and for cyclists riding straight through an intersection to be struck by right-turning motorists.

To overcome this gap between current and Safe System performance, safety platforms or raised intersections have been trialled in the Netherlands (and potentially other countries in Europe). The results of evaluating these trials show that vehicle speeds at the points of conflict can be brought to within the Safe System boundary condition when ramps of an appropriate gradient are used. An example of a successful trial in the Victorian town of Belmont, at the intersection of the Surfcoast Highway and Kidman Avenue is shown in Figure 4.38. Early indications of performance at this trial intersection have been very positive, with substantial reductions found in the speed of vehicles passing through the intersection signals. Other evaluations of safety platforms are underway in Victoria.

Figure 4.38: Signalised intersection with 50 km/h safety platforms (Surf coast Highway/Kidman Avenue, Belmont Victoria)

This safety enhancement to traffic signals operation has demonstrated superior performance in the Netherlands, with a 40-50% reduction in injury producing crashes when retro-fitted to existing signals (Fortuijn et al., 2005). While the original purpose for the safety platforms in NL has been to better protect cyclists and pedestrians when crossing busy, higher speed roads, vehicle occupants have also benefited substantially. To operate intersection signals to achieve Safe System risk levels for pedestrians and cyclists, safety platforms designed to be traversed at around 30-40 km/h may be needed. Further development and trial of design concepts are needed to provide objective evidence on the possible impacts of safety platforms specifically on both pedestrian and cyclist safety, and on route efficiency.

Signalised 'Tennis Ball' intersections

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓	✓✓	

A new design for intersection signals has been trialled at the intersection of Roe Highway and Berkshire Road in the Perth suburb of Forrestfield. The trial consisted of a new geometric layout for an adjacent pair of intersections formed by the creation of a grade-separated intersection with diamond interchange facilities (Figure 4.39 and Figure 4.40). The basic principle involved using roundabout style islands that allowed turning-drivers and riders to follow their normal paths by cutting through gaps in the generally circular island within each intersection. Through-vehicles, which present the greatest threat to safety, even when travelling at legal speeds, are slowed by the roundabout-style geometry and any conflicts are likely to happen at more favourable angles than 90° and at lower speeds. An evaluation of the performance of this new design (Nichols, 2017) showed that 99% of vehicles passing through the intersection do so at or below the Safe System threshold for vehicle occupants of 50 km/h. This compares with a normal layout in which only 30% of vehicles pass through at 50 km/h or less.

While the trial involved treating a pair of interchange intersections formed as a result of grade-separation, the 'Tennis Ball' design can be used at individual intersections by applying the principles of reducing the likelihood of vehicles passing through at greater than 50 km/h.

Figure 4.39: 'Tennis Ball' signalised intersections at Roe Highways/Berkshire Road, Forestfield, Perth

Figure 4.40: 'Tennis Ball' signalised intersections at Roe Highways/Berkshire Road, Forestfield, Perth

Lower travel speeds compared with the conventional signalised intersection signal design will reduce crash likelihood for pedestrians and cyclists but still not achieve Safe System risk levels for pedestrians and cyclists; to achieve Safe System risk levels, safety platforms or greater horizontal deflection will be needed to induce lower vehicle speeds (i.e., 30 km/h) where vehicles conflict with pedestrians and/or cyclists.

Between intersections – Grade-separation of pedestrians and cyclists from vehicular traffic

Injury Severity	Crash Likelihood	Exposure to Conflicts
	✓✓✓	

In simple safety terms, the most effective form of separation for pedestrians needing to cross Movement Corridors and Connectors is to provide pedestrian bridges, elevated roadways or tunnels. This allows road crossings to be undertaken without the risk of collisions and traffic to move with fewer interruptions to flow. While very good examples of grade-separation for pedestrians exist, they can impact negatively on surrounding urban space and sometimes require pedestrians to undertake inconvenient diversions to their journeys or take a path that threatens personal security. Over the length of many Movement Corridors and Connectors, it will be impractical to provide adequate coverage for pedestrians or cyclists. The mechanism for reducing the risk of pedestrian (or cyclist) crashes through grade-separation is to reduce crash likelihood through vertical separation, while exposure remains essentially unchanged.

Figure 4.41 shows a grade-separated facility for pedestrians and cyclists using Warrigal Road. In this particular case, the overpass connects with a significant metropolitan off-road cycle route. Figure 4.42 shows a Dutch example of a tunnel under the equivalent of a Movement Corridor and Connector.

Figure 4.41: Grade-separation for pedestrians and cyclists on Warrigal Road, City of Monash, Melbourne

Figure 4.42: Grade-separation for pedestrians and cyclists on Connector Road (the Netherlands)

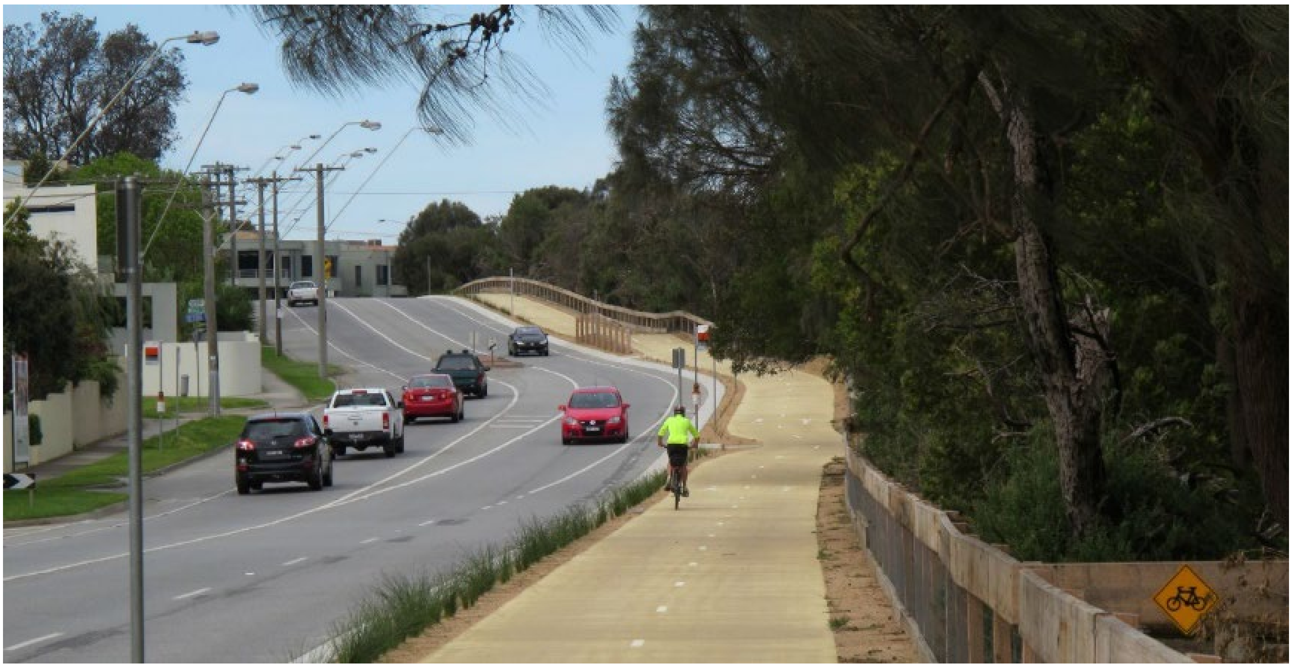
Separated cycle facility

Injury Severity	Crash Likelihood	Exposure to conflicts
	✓✓✓	

For cyclists travelling along Movement Corridors and Connectors with speed limits above 30 km/h, it will be necessary under a Safe System approach to provide separated cycle facilities. This entails full separation of cyclists from motor traffic. Because Movement Corridors and Connectors typically have speed limits of 60, 70 or 80 km/h, it is imperative that segregation from traffic occurs for the safety of riders. This type of facility acts almost entirely on crash likelihood, as the numbers of drivers and riders will typically remain unchanged (they may even increase), and the speeds of both cyclists and motorists will also remain largely unchanged.

Figure 4.43 shows an example of a shared path cycle facility along a Movement Corridor and Connector in Melbourne, which is a very popular cycling route for both on- and off-road riding.

Figure 4.43: Shared path beside a Connector Road (Beach Road, City of Kingston, Melbourne)

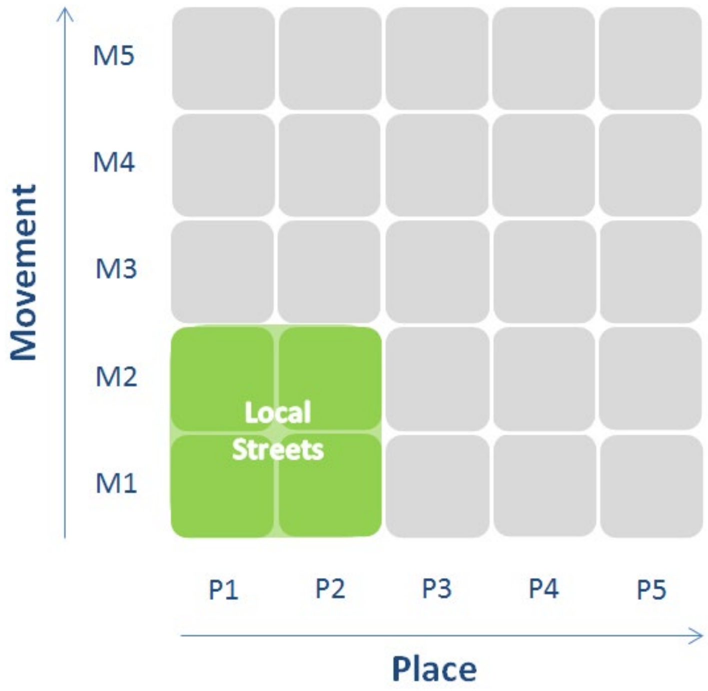


4.7 Local Streets

4.7.1 General Description

Successful Local Streets should provide quiet, safe and desirable residential access for all ages and abilities that foster community spirit and local pride. They are part of the fabric of our neighbourhoods, where we live our lives and facilitate local community access (DoT 2019).

Figure 4.44: Local Streets on the Movement and Place Framework



4.7.2 Key Movements in Local Streets

The key movement considerations in Local Streets are outlined below.

- Pedestrians: walking is a basic form of movement that needs to be accommodated in Local Streets. While volumes are rarely highly concentrated, the need to cross and move along streets is usually present throughout entire networks of Local Streets. People of all age groups walk in local streets, including children and older people who are among the most vulnerable pedestrians.
- Cyclists: cycling is also commonplace in local streets, both within the local street system and for access to and from the higher movement roads. Children riding to and from school should be assigned priority when using Local Streets, as should elements of principal cycle networks that pass along Local Streets.
- Public Transport: buses are the most common form of public transport in Local Streets. Adequate provision for their safe and efficient operation is a basic requirement of Local Street design.
- General traffic: access for general traffic is a fundamental aspect of the safe and efficient functioning of Local Streets. The primary emphasis for movement of general traffic is to provide access to and from properties, predominantly residential, and to connect properties with roads of higher movement function.
- Freight: Local Streets should aim to provide safe and efficient access to freight, especially on local roads in industrial areas and precincts. However, rather than aiming to prioritise movement, the emphasis on the design and operation of Local Roads should be on providing access.

- Other: as with other M&P families, appropriate access must be provided for emergency services, delivery vehicles, municipal service vehicles and construction vehicles of reasonable size for Local Street purposes should also be accommodated in the street design philosophy. In future, Local Streets may also need to facilitate the safe movement of small autonomous vehicles, as well as a variety of innovative mobility vehicles and devices that are currently emerging in society (e.g., e-scooters, bikes and skateboards, electric scooters for the ageing/mobility impaired, and an assortment of other means of moving over relatively short distances, in the range of up to 10 km).

4.7.3 Key Places in Local Streets

The key place features of Local Streets are outlined below:

- residential dwellings
- local public transport bus and tram stops
- community facilities
- parkland, playgrounds and sporting fields
- schools and kindergartens.

4.7.4 Safe System Measures for Pedestrians and Cyclists in Local Streets

The provision of Safe System aligned measures for pedestrians and cyclists along Local Streets will, ideally, focus primarily on speed management, supported where needed with investment in traffic-calming infrastructure to achieve low-risk travel speeds. Based on the above, potential Safe System-aligned measures for pedestrians and cyclists for Local Streets are described below and summarised in Table 4.6.

Table 4.6: Local Streets – Summary of Safe System aligned pedestrian and cyclist measures

Safe System treatment	Indicative cost
At intersections in Local Streets	
All-way stop signs	$
Restricted access intersection	$$
Raised intersections with 30 km/h ramps	$$
Safety platforms (30 km/h or lower) on all approaches	$$
Roundabouts with 30 km/h wombat crossings	$$$
Between intersections in Local Streets	
30 km/h speed limits	$
Playground zones	$
On-road cycle lanes (30 km/h)	$
Shared use by cyclists of general traffic lanes (30 km/h)	$
Wombat crossings (30 km/h)	$$
Speed platforms (30 km/h)	$$
Kerb outstands/blisters and pedestrian refuges (30 km/h)	$$
Road narrowing (30 km/h)	$$
Horizontal deflection (30 km/h)	$$
Textured or coloured pavements (30 km/h)	$$
Shared space (10 km/h)	$$
Exposure reduction/redirection of through traffic	$$$

Some of these measures are described more fully following for the stereotypical case and, where feasible, illustrated with photographs or other images. All treatments are covered in more depth in Appendix B.

A Stereotypical Case – City of Vincent Perth

The report uses Perth's City of Vincent suburban areas to illustrate the types of measures that are being or could be implemented in Local Streets to deliver Safe System risk levels. The pedestrian and cyclist measures presented in this section are considered generically relevant to Local Streets though not necessarily specifically suited to the local streets described in this Perth case study. Some measures may prove impractical, however, they convey important principles for designing and operating for Safe System outcomes for pedestrians and cyclists. *Figure 4.45* shows a typical local street scene in the City of Vincent.

Figure 4.45: Local Street in the City of Vincent Perth

Source: Photo courtesy of the City of Vincent

Local streets enable people to move within the local neighbourhoods, between their homes, families, friends, schools and other community facilities. Importantly, they also connect communities with the major road system designed and operated for efficient travel for high numbers of users. As well as providing access to and from residential and other community-based properties, and the major roads, local streets also help to define communities and the character of their neighbourhoods.

In contrast with Movement Corridors and Connectors, local streets do not prioritise moving large numbers of people with high efficiency. In local streets, reliable access is a primary goal, as is the creation of peaceful and aesthetic surroundings. By supporting the active modes, reliance on private cars can be moderated, especially for local trips. This further enhances street quality and supports sustainable urban mobility.

While it is of fundamental importance to provide safe and reliable access for general traffic, and other forms as outlined above, travel times are of lower priority in Local Streets. This is because Local Streets typically make up a small proportion of typical journey times. Furthermore, the evidence on the role of travel speeds on crash and injury risk is both indisputable and especially influential for pedestrians, cyclists and motorcyclists, and other unprotected road users. Accordingly, local streets should be designed to elicit moderate travel speeds to assure the safety of all vehicle occupants, as well as the active modes, which should be of high priority in Local Streets. Any impact on travel times will be minimal in the context of normal journeys. The creation of peaceful and attractive surroundings are much-valued by residents and can add value to properties along Local Streets.

Pedestrian and cycling movements

To deliver Safe System aligned measures for pedestrians and cyclists in Local Streets, the main focus should be on successful speed management and on the minimisation of the exposure of pedestrians and cyclists to extraneous vehicular traffic. Safe and convenient access for general traffic to and from properties and local facilities is also essential, while minimising travel time is of lower importance. While the Place value of Local Streets is not high at the National or State levels, the sense of Place is highly-valued by communities at the local level.

In general, pedestrians and cyclists should be prioritised within local streets, with other modes, such as bus services and emergency services, receiving priority in terms of appropriate levels of access to fulfil their roles, while generally not implying high mobility.

4.7.5 Safe System Priority Treatments

To deliver Safe System aligned measures for pedestrians and cyclists, the emphasis of treatment philosophy in local streets is on managing speeds as, typically, separation is not a practical option. There may, however, be exceptions to this general approach.

Speed limit setting

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Current speed limits in local streets are, by default, 50 km/h. Many local councils concerned about the safety of pedestrians and cyclists within their municipalities have managed to reduce local street speed limits in defined locations to 40 km/h. These cases usually aim to enhance safety around schools, central business districts and shopping areas. Notwithstanding these efforts to enhance safety, the vast majority of local street length is 50 km/h by default. A small number of municipalities across Australasia, for example, the Cities of Auckland and Wellington (NZ), the Cities of Yarra and Port Phillip (Melbourne) and the City of Vincent in Perth have trialled 30 km/h in local streets and in CBD environments.

Because of the strength of evidence linking speed with pedestrian (and cyclist) crash and injury risk, and noting the higher risk of crash involvement among child pedestrians, the case for setting 30 km/h speed limits around schools is solid. While it is now common practice for 40 km/h to apply around schools, often on a part-time basis, consideration should be given to enhancing the effectiveness of treatments for pedestrians and cyclists in the vicinity of schools by using 30 km/h instead of today’s 40 km/h limits. The primary safety effect of lowering speed limits is to reduce crash and injury risk, however, in some circumstances, exposure-based benefits may arise where motorists choose alternative routes to avoid perceived increases in delays.

There has been long-standing discussion and debate about the long-term effectiveness of introducing lower speed limits in local streets (i.e., below the 50 km/h urban default) without also constructing supporting traffic-calming infrastructure. One approach to reducing travel speeds to 30 km/h, at minimum costs, which could be trialled would involve:

- introducing area-wide 30 km/h speed limits (or 40 km/h if a staged approach is preferred), while recognising that many drivers will comply, regardless of whether they support the initiative. This shift in behaviour will bring average speeds down and, hence, immediately lower crash and injury risk. Other measures, such as enforcement and public education, can be used to encourage non-compliant drivers and riders to comply. Area-wide speed limits will reduce the proliferation of signing, which can be an unsightly feature of neighbourhood streets, where visual amenity is highly-valued by residents
- monitoring speeds post-treatment (i.e., introduction of 30 km/h area wide speed limits) to see where speed behaviour requires further attention

- where further attention is needed, introducing traffic-calming treatments at the entrance to individual areas and/or within areas to address locations of 'systemic' risk, such as at intersections which are, of course, locations where crash risk is highly concentrated. By treating intersections to bring speeds down, not only will speeds be reduced at these locations, but speeds on local streets, between intersections, will also be addressed
- by continuing to monitor speeds on neighbourhood streets and, only where needed, adding more traffic calming infrastructure (or other measures, such as mobile speed feedback signs).

This approach allows the impacts of low-cost, area-wide speed limits in local streets to be assessed, while investing in traffic-calming infrastructure only where needed. A trial of this approach in communities wishing to achieve lower travel speeds will present opportunities to learn about the longer-term effectiveness of a staged approach reducing travel speeds in local streets.

While 30 km/h speed limits in local streets offer the simplest and lowest cost means of designing for Safe System risk levels for pedestrians and cyclists, the current default speed limit is 50 km/h and there is little evidence at the political level of the road and traffic engineering professions being supported to reduce the default urban speed limit to 40 km/h. Even at 40 km/h, significant investment in infrastructure is needed to provide separation from vehicles or to secure travel speeds to low risk levels for pedestrians and cyclists.

Figure 4.46 shows how 30 km/h has been introduced in Local Streets within the Perth municipality of Vincent. Highly conspicuous markings on the pavement help to alert drivers to the new 30 km/h speed limits.

Figure 4.46: 30 km/h Local Street speed limit in the City of Vincent Perth

Source: Photo courtesy of the City of Vincent

While the evidence indicates that 30 km/h is the optimal travel speed for the safety of pedestrians and cyclists, achieving 30 km/h is not straight forward today in many parts of Australasia. Given the evidence on the role of speed, together with the higher risk of crash involvement among children, schools are well-suited to trial 30 km/h local street speed limits. Where it has not been possible to achieve 30 km/h, a range of measures can be considered, in conjunction with 40 km/h limits, to align with Safe System values. These measures should be designed for 30 km/h or lower travel speeds, even though the speed limit may be 40 km/h or possibly the 50 km/h default.

At intersections

To assure low risk of serious injury at intersections, vehicle travel speeds should remain at or below 30 km/h. If this can be achieved, together with a low risk of a crash occurring, pedestrians and cyclists should be able to negotiate intersections with very low chances of being seriously injured or killed in a collision with a vehicle.

Local street roundabouts

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	

Local street roundabouts are the ideal form of control for the intersections of local streets. They assign equal priority to roads of generally similar status, slow traffic to speeds that are highly survivable should a crash occur, even for pedestrians and cyclists, and reduce crash likelihood. They can also serve to reduce the extent of 'rat-running' through local streets. Notwithstanding these positive features, urban roundabouts should be designed with the specific needs of pedestrians and cyclists in mind. That is, roundabout geometry should be designed to achieve travel speeds below 30 km/h. Figure 4.47 shows a local street roundabout close to local shops and cafes, which generates significant pedestrian and cyclist activity for much of the typical day, throughout the week.

Figure 4.47: Local street roundabout in the City of Port Phillip, Melbourne

All-way stop signs

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓	✓✓	

Though not used extensively in Australasia, all-way stop signs offer potential for use in local streets where the need to assign priority to one street over another intersecting street is much weaker than at intersections where at least one of the intersecting roads has a high movement value. While all-way stop signs don't offer a physical incentive for drivers to comply, they can be expected to operate at Safe System risk levels when the speed limit is 30 or 40 km/h. Even with Safe System aligned measures such as safety platforms and roundabouts, drivers and riders can still choose to exceed design speeds. Should this prove to be the case, strengthening measures can be considered. Figure 4.48 shows an example from Banff, Canada. Because they are not used in Australasia to any significant extent, all-way stop signs could be used on a trial basis, assessed in terms of their safety performance and, if needed, strengthening measures added to bring them into closer alignment with Safe System operation.

Figure 4.48: Four way stop signs used in a City Street setting in Banff, Alberta Canada

Raised intersections with 30 km/h ramps

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Raised intersections with 30 km/h ramps are well-suited to Local Streets, both as a means of delivering Safe System performance for pedestrians and cyclists (and all other road users) and of contributing to Local Street traffic-calming. While they achieve their effects primarily by reducing crash and injury risk, some motorists may be diverted to other routes to avoid lower speed limits (i.e., exposure reduction). Figure 4.49 shows raised intersections in the City of Vincent, constructed as part of the City's safe active travel initiative.

Figure 4.49: Raised intersections with 30 km/h ramps - City of Vincent, Perth

Source: Photo courtesy of City of Vincent

Restricted access intersection

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓✓

Even in local streets, cross-road intersections present the greatest concentration of conflict points for vehicular traffic, as well as for pedestrians and cyclists. A design form has been developed to reduce the number of conflicts for all road users, and to create lower risk speeds and conflict angles. A small roundabout can be used at local street intersections to direct traffic to make turns while still allowing cyclists to pass through the intersection. In a low speed setting, such as 30 or 40 km/h, this design form would be aligned with Safe System principles for cyclists, as well as for pedestrians.

Figure 4.50 shows an example of a restricted-access small roundabout at a local street intersection in Vancouver, Canada. In this setting, the speed limit is 30 km/h.

Figure 4.50: Restricted access roundabout in Local Streets, Vancouver, Canada

Between intersections

A number of types of measure can be applied to local streets between intersections. As elaborated elsewhere in this report, pre-impact travel speeds in fatal collisions with pedestrians are often also the impact speed. It is therefore advocated that speeds must be moderated to around 30 km/h. When applied to local streets, measures which achieve travel speeds not exceeding 30 km/h become the favoured approach for eliminating pedestrian and cyclist deaths and serious injuries. Additional measures can be considered to reduce crash risk, as well as secure speeds to Safe System levels.

Road narrowing

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓✓	✓

Figure 4.51 shows a Swedish example where the road has been narrowed to one lane at the location of a bus stop on a local street. The purpose of the narrowing is to prevent any other vehicle movements while passengers are boarding or alighting from the bus. In this way, passengers – school children and older or mobility-impaired people, in particular – are not at risk of being struck by cars overtaking the bus during the boarding/alighting stage. The delays to individual motorists are minimal and in aggregate insignificant on a network-wide scale. This form of safety measure can be employed in local streets more generally to support lower travel speeds, as well as encourage public transport use and discourage ‘rat-running’ by motorists.

Figure 4.51: Road narrowing at Local Streets bus stop in Gothenburg, Sweden, to prevent overtaking by general traffic

Horizontal deflection

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓	✓✓	✓

Another way of achieving vehicle travel speeds that align with Safe System risk levels (i.e., 30 km/h or lower) is through changes in horizontal alignment. A variety of geometric treatments can be designed to affect reductions in travel speed below the 50 km/h default, by requiring vehicles to undertake a lateral movement to proceed along a street. Vertical deflection, using speed platforms, is generally regarded as more effective than horizontal deflection, however, vertical deflection may not suit all local street situations. Because the effect on travel speed does not necessarily extend beyond a limited range of influence, these measures may need to be repeated along a route or across an area to have the desired spatial coverage. Figure 4.52shows a Local Street horizontal deflection treatment in a Local Street in the City of Vincent in Perth. This treatment and a variety of others were introduced as part of the City's Safe Active Travel initiative which seeks to promote safe walking and cycling within the municipality.

Figure 4.52: Horizontal deflection in 30 km/h Local Street setting in the City of Vincent, Perth, WA

Source: Photo courtesy of the City of Vincent

On road cycle lanes with adequate lateral clearance (with 30 km/h speed limits)

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Low-risk cycling on local streets can be achieved in a number of ways. Physical separation is the most effective though not always feasible in narrow streets where vehicular access is also required. Historically, some local streets were designed with generous widths, allowing the retro-fitting of separated cyclist paths to the street cross section, while still adequate, though potentially restricted widths for motorists (refer Figure 4.53, below). There are two main forms of on-road cycle lane suitable for use in local streets:

- Ideally, the cycle lane would have an adequate clearance distance between the cycle lane and parked cars, to avoid car doors being inadvertently opened into the path of the cyclist.
- Where an adequate clearance distance cannot be provided (and on-street parking cannot to be removed), speed limits should not exceed 30 km/h to help ensure cyclists do not impact car doors above this speed. An impact between a cyclist and a car door at 30 km/h is still severe and could result in a fatal outcome, especially if the cyclists were to fall and be run over by following traffic.

By reducing the speed limit to 30 km/h along local streets, cyclists can be permitted to share the general traffic lane, while still meeting Safe System principles.

An innovative example of a local street cycle lane is shown in Figure 4.53, whereby two-way cycling is permitted on a street that is restricted to one-way movement for general traffic. On-street parking has been confined to one side of the street, thereby allowing cyclists to use the general traffic lane when heading in the same direction and to use the cycle lane when heading in the opposite direction to general traffic. The risk of car-dooring incidents is low in this design layout.

For Local Streets forming part of a principal cycle network, higher quality facilities will generally be desirable when compared with normal cycling levels in neighbourhood streets. Where possible, segregation of cyclists from general and other traffic should be provided, including specific crossing facilities where cycle paths intersect with Local Streets. These facilities would, ideally, take the form of platform crossings signed to give priority to cyclists over motorists and, moreover, designed to achieve speeds below 30 km/h.

Figure 4.53: Two way on-street cycle facilities on a one way street (Strathcona, Edmonton)

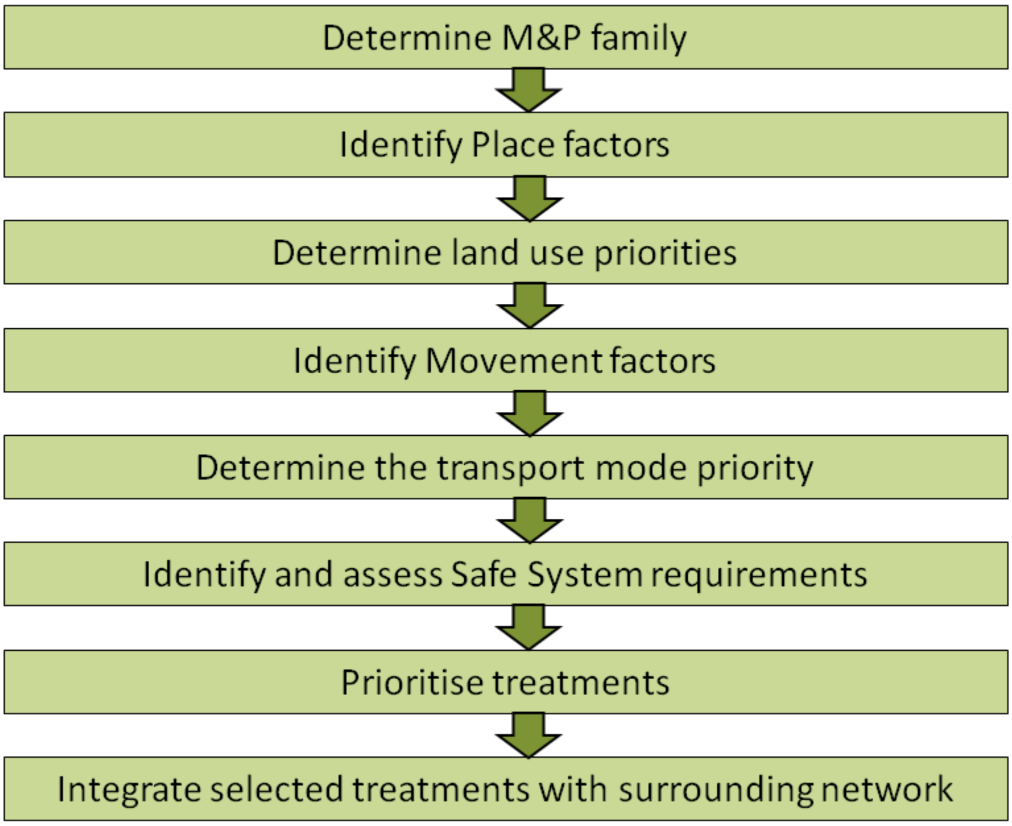
5. Concluding Comments

5.1 Guidance for Practitioners on Application

To assist readers of this report to appreciate how its content is intended to be used, a simple eight-step process has been developed. Figure 5.1presents the process diagrammatically.

1. Determine the appropriate M&P family.
2. Identify the factors that are driving the Place function.
3. Determine the land use qualities that are to be supported and prioritised.
4. Identify the factors that are driving the Movement function.
5. Determine the transport modes to be prioritised.
6. Identify and assess options for assuring Safe System conditions for pedestrians and cyclists.
7. Prioritise treatments that align with and enhance the Place values of the area.
8. Integrate selected pedestrian and cyclist measures within an overall plan for roads, streets and land use.

Figure 5.1: Diagrammatic representation of process for use of this report



5.2 Physical Separation or Lower Travel Speeds

This project has affirmed that, to deliver Safe System–aligned risk levels, travel speeds of 30 km/h or lower are needed where vehicles are able to interact with pedestrians and cyclists. If these speed conditions are found to be in conflict with M&P considerations (e.g., lower speeds being judged incompatible with the desire for high movement function and/or the perception of low place values), effective physical separation is required to meet Safe System principles. Where these principles cannot be met, pedestrians and cyclists will remain exposed to unacceptable levels of risk when attempting to cross roads or cycle along them. While this logic is simple and clear, it presents challenges for society in deciding what comes first – protecting the lives and long-term health of individuals or maximising the efficiency of the road transport system to deliver mobility and access.

Today, society is not unanimous in its views on this highly-challenging ethical issue. Some voice their opinions that speed limits should be raised, others that they should remain unchanged. A prime reason offered is to protect national and local economies. Others express their frustrations at driving so slowly. Yet others are highly supportive of lower limits, especially when considered in terms of the benefits to walking, cycling, liveability, sustainable urban living and to population health.

If the safety of all road users is truly paramount, especially our highly vulnerable pedestrians and cyclists, children and older citizens, major change is required. Continuing to ‘hope’ we can educate people to behave safely, all of the time, has proven unrealistic. A more fundamental shift of approach in thinking is needed.

Thus, the dilemma and major challenge for New Zealand’s and Australia’s futures is to decide where we can:

- accept lower speed limits/travel speeds, and so avoid the need for physically separation, and
- provide effective physical separation to allow higher speeds to meet movement objectives.

Where the retention of high speeds is required for economic reasons, increased levels of funding will be needed to build the infrastructure required to physically separate pedestrians and/or cyclists from vehicles. But a major shift in methods of prioritisation will be needed, as current economic criteria will rarely lead to such funding being provided. Benefit-to-cost Ratios will often not exceed the minimum requirement of 1, largely because crash histories are insufficient to reach the funding threshold. The consequence of continuing with traditional economic criteria to prioritise infrastructure investment will place increasing pressure on the use of speed management, especially lower limits. Alternatively, the status quo will prevail, and with it a steadily growing problem of road trauma involving cyclists and pedestrians.

Where lower speed limits are preferred over physical separation, significant leadership and community/political engagement will be needed to address the current (sometimes) vocal resistance in communities and among some stakeholders. Considerable progress has been made across Australasia with the implementation of 40 km/h speed limits where (higher-risk) walking and cycling predominate. In general, the economic impacts feared by early opponents have not eventuated and opposition has been short-lived.

Regardless, it is unclear whether communities as a whole are ready for 30 km/h in selected settings. This means that new ways will be required to manage speeds to safer levels for pedestrians and cyclists, as well as to support the value of Place. It is therefore suggested that an implementation strategy for the two key parts of the overall approach to protecting pedestrians and cyclists be developed. This would involve:

- reviewing current approaches to prioritising investment in infrastructure to enable physical separation of vulnerable road users to occur on roads requiring high speeds for economic reasons
- developing a comprehensive approach to community and stakeholder engagement, to raise awareness to the scientific facts surrounding the fundamental role of speed in determining crash and injury risk for vulnerable road users, and the potential for protecting these groups, while also supporting the many keenly-sought qualities of Place, such as at schools, in community centres, at sporting grounds, in city environments, and around public transport hubs.

5.3 Place-making

One of the key benefits of adopting the M&P approach is to bring greater attention to aspects of Place and, therefore, a better balance between the primary objectives of M&P. While mentioned from time to time throughout this report, the importance of place-making to support the qualities of Place has not been a particular focus. Different types of enhancement to the values of Place can be made, depending on the choice of Safe System-aligned measures for pedestrians and cyclists.

By their nature, some types of Safe System-aligned measures will enhance the value of place, particularly by enabling the planting of trees, both for shade and aesthetics, the provision of seating, the construction of shelters from rain, shade structures, and improved street and place lighting, especially around public transport centres, safer and more conducive conditions for footpath dining, and a range of other features that deliver greater priority for pedestrians and cyclists. Wider footpaths, medians, refuges, kerb blisters, roundabouts, shared space, car-free streets, pedestrian malls, segregated pedestrian and cycle paths, even architecturally-designed, grade-separation in the appropriate settings, are among the measures that can actively contribute to place-making because of the way in which space is utilised. Lower travel speed can also enable more aesthetic designs that might not otherwise be Safe System-aligned at higher speeds. For example, pedestrian and/or cyclist treatments that involve vertical and/or horizontal deflection, and/or surface treatments can enhance place-making efforts, and hence support the values of Place.

The inclusion of such features, while supporting the place-making objectives, may be in conflict with Safe System principles in some M&P settings. For example, the planting of trees alongside Movement Corridors and Connectors where, by definition, it is deemed important to enable high travel speeds, will need resolution. Other types of conflict will undoubtedly arise in the process of seeking to create truly safe forms of travel, that are also as efficient as can practically be provided, and that respect and build the values of place through which traffic, including pedestrians and cyclists, passes.

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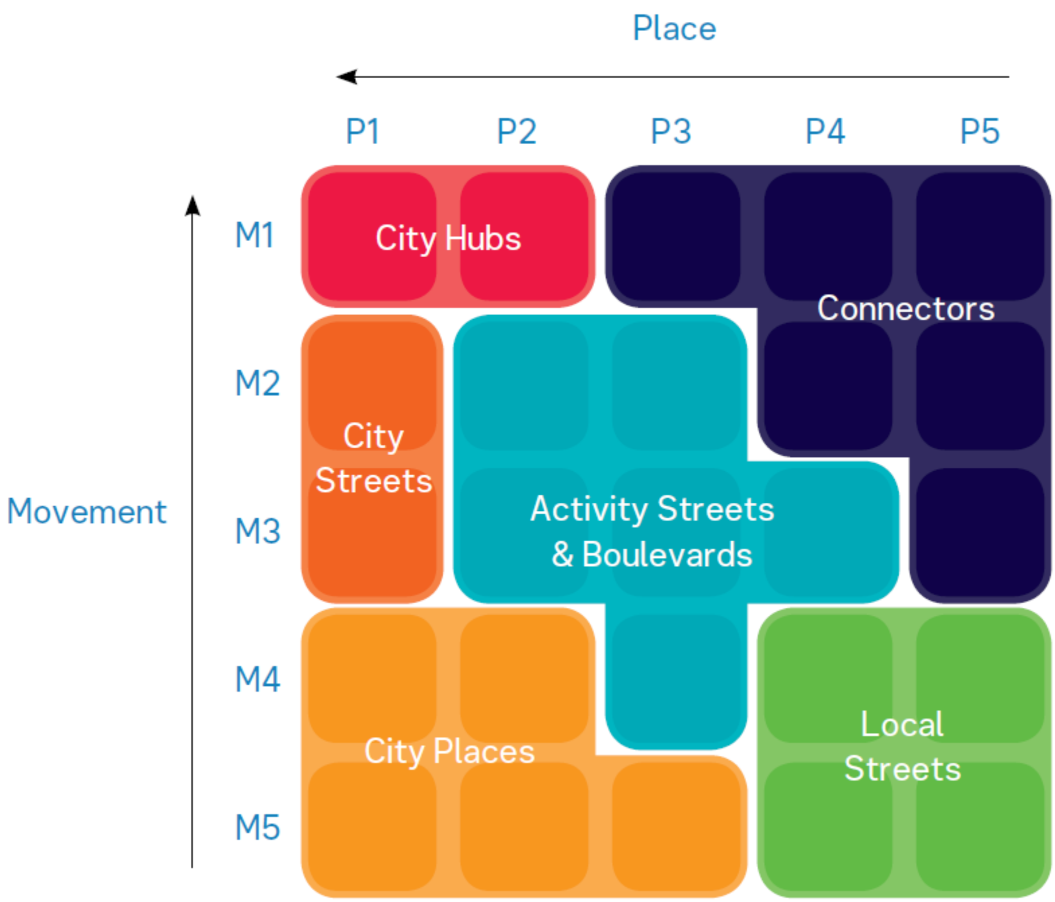
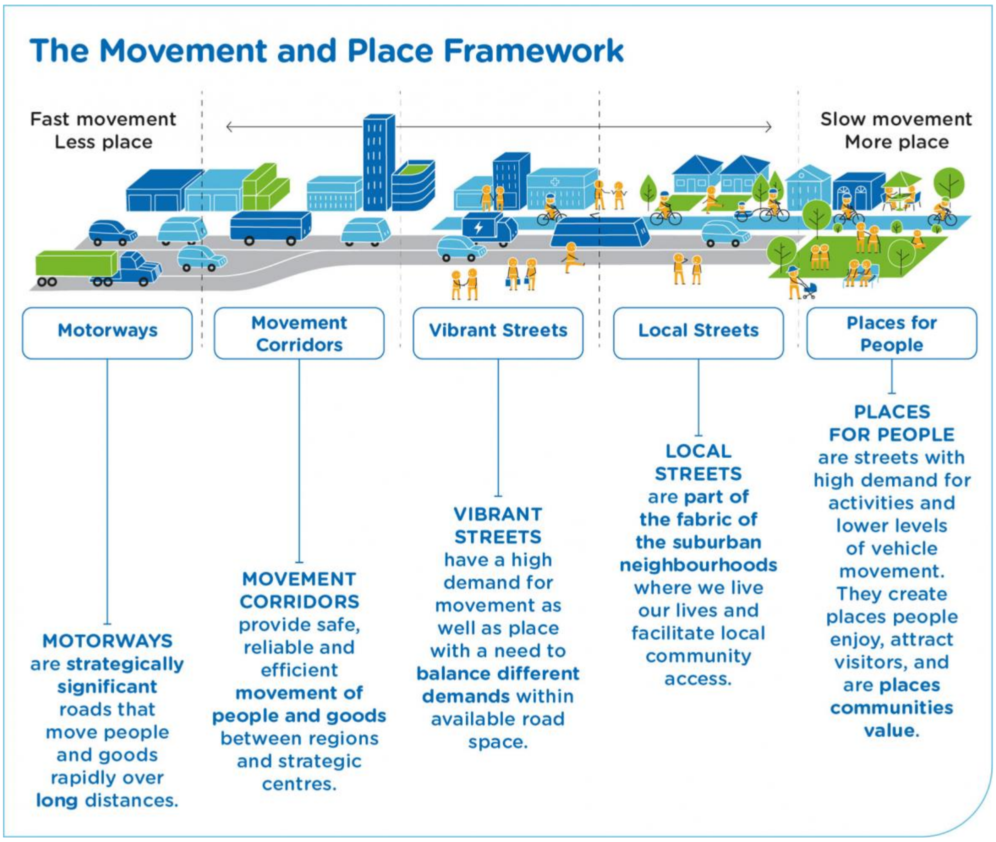
Appendix A Movement and Place Frameworks of Leading Australasian Jurisdictions

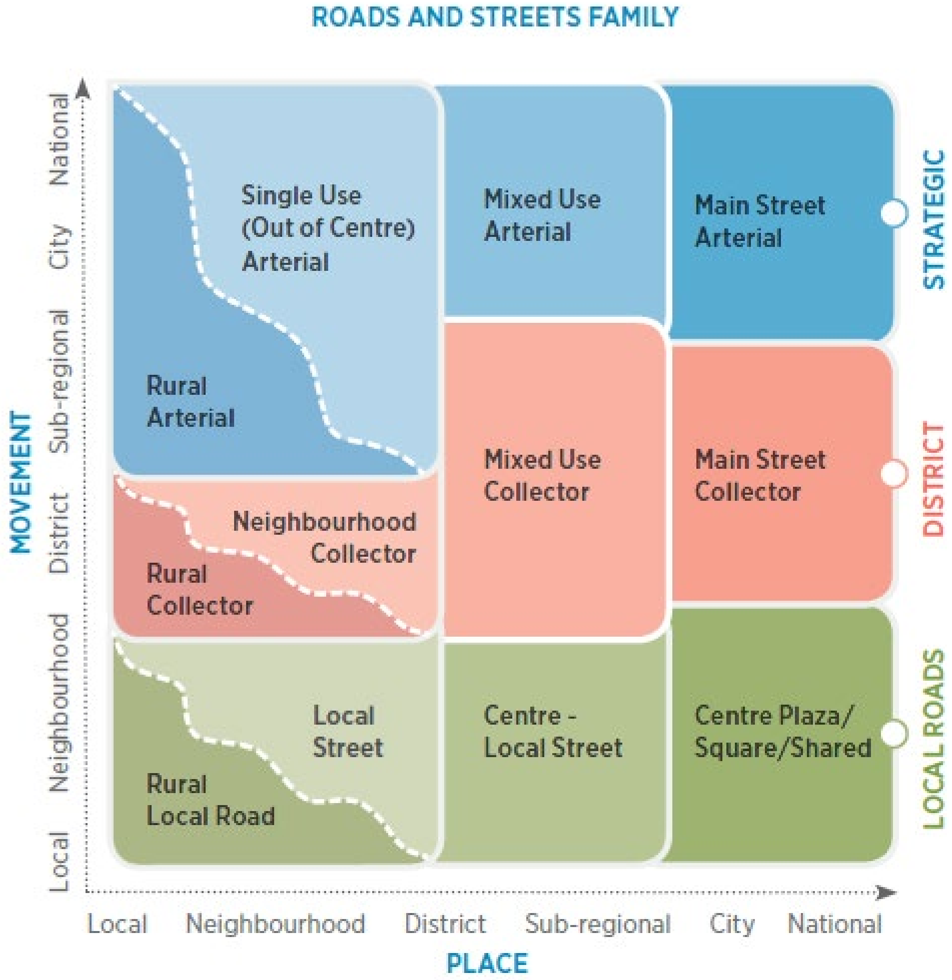
A.1 Victoria



A.2 New South Wales



A.3 City of Auckland



Appendix B Safe System Aligned Measures for Pedestrians and Cyclists

The extent to which each treatment aligns with Safe System principles is summarised immediately following each treatment heading. The assessment focuses on injury severity, crash likelihood and exposure, with the number of ticks (✓) indicative of both the mechanisms and strength of effects. Three ticks means a strong contribution to reducing risk, two ticks a medium contribution and one tick is a weak contribution. The absence of a tick indicates that the treatment makes no appreciable/direct contribution to reducing risk for the particular variable being considered.

By way of example, a well-designed roundabout is expected to reduce the travel speed through an intersection to 30 km/h, thereby receiving three ticks. The lower speed at roundabouts has a medium effect on crash likelihood though crashes will still occur at low severity. In general, roundabouts have no effect on exposure (unless they divert traffic to other locations or shift drivers to other modes or not to travel at all).

The Safe Systems treatments for each street type do not represent an exhaustive list. Existing or potential new designs that meet Safe Systems principles should be used wherever possible. While the measures described in Section 3 provide many of the currently known examples, good designers will find or develop new and highly innovative design forms in the future to deliver safe mobility for pedestrians and cyclists. This underlines the vital role of innovation in eventually eliminating severe road trauma.

A number of the treatments refer to public transport and in particular trams. Where trams are mentioned, this can generally be regarded as also including Light Rail Vehicles (LRV).

B.1 At Intersections

To avoid death or serious injury being sustained by a pedestrian or cyclist negotiating an intersection, it is fundamentally important that vehicle travel speeds do not exceed 30 km/h. If this can be achieved, together with a low risk of a crash occurring, Safe System risk levels will have been achieved for these two highly vulnerable and rapidly growing road user groups.

B.1.1 Roundabouts with wombat crossings

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	

Roundabouts are excellent at achieving low injury risk levels for vehicle occupants, as they reduce impact forces in the circulation lane. More specifically, they simplify decision-making, dramatically reduce the number of conflict points compared with a conventional cross or T-intersection, and reduce vehicle speeds and conflict angles to survivable levels should a crash occur. For cyclists, the reduction in conflict angles produces significant reductions in the risk of severe injury, in addition to the reductions in impact speeds. However, in their basic form, roundabouts provide facilities of only modest standard for pedestrians and cyclists. Additional measures, ideally raised zebra crossings on all approaches, are needed to assist pedestrians to cross safely. Compared with intersection signals, the inherent threat to life and long-term health is much reduced in the event of a collision. Subject to available space, suitable landscaping of a roundabout and its approach islands can be carried out to improve overall amenity in busy places. Single-lane layouts, with approach lanes shared by cyclists and motorists, are favoured, provided the speed environment is low. Figure B.1 shows an example of a roundabout in a city street in the Mackay, Queensland.

Figure B 1: Roundabout with wombat crossings Mackay, Queensland

Multi-lane roundabouts generally allow faster approach speeds, making them less beneficial for pedestrians and cyclists. In higher speed settings (80 km/h or above), multi-lane roundabouts are typically designed to allow faster entry speeds, which places pedestrians and cyclists at greater risk, often outside the Safe System boundary. Further work may be needed either to confirm that current roundabout designs work well or that strengthened design forms, which either separate vulnerable road users or bring speeds to low-risk levels, are needed. Zebra crossings are not commonly used on multi-lane roads. To fill the existing safety gap for pedestrians on multi-lane roundabouts and/or in higher speed settings (above 60 km/h), either a review of current practices or the development of a new, Safe System-aligned treatment form is needed.

Makwasha et al. (2017) reported reductions of around 60-80% in pedestrian casualty crashes from the construction of roundabouts. Even greater gains are likely when wombat crossings are incorporated.

B.1.2 Threshold platforms

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	

Pedestrians crossing local side-streets where they intersect with Activity Streets and Boulevards are exposed to the systemic risk of being struck by left- or right-turning traffic off the Activity Street or Boulevard. A corresponding form of systemic risk for cyclists involves motorists turning right into or leaving local side-streets without giving way to approaching cyclists on the Activity Street or Boulevard. The risk of crashes and the severity of any resultant impacts can be moderated by threshold platforms that will help to slow turning vehicles into or out of the local side-street. Figure B.2 shows an example of a threshold platform at an intersection between an Activity Street and a local street. The design of threshold platforms also ensures that pedestrian movement is given greater prominence and ease of use for pedestrians walking along the Activity Street or Boulevard. This is achieved by virtue of the continuity of footpath level afforded by the basic design. This treatment does not change the existing give way requirement of drivers, however, unless the threshold platform is accompanied by, for example, a zebra crossing that expressly gives priority to pedestrians on the cross-walk. At locations of high pedestrian and/or vehicle volumes, a zebra crossing (with static signing only) can be added to prioritise pedestrian crossing movements.

Figure B 2: Threshold platform at a side-street intersection with an Activity Street in a Melbourne suburb

B.1.3 All-way stop signs

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓	✓✓	

Though not used extensively in Australasia, all-way stop signs have the potential for use in local streets where the need to assign priority to one street over another intersecting street is much weaker than at intersections where at least one of the intersecting roads has a high movement value. While all-way (or four-way) stop signs don't offer a physical incentive for drivers to comply, they can be expected to operate at Safe System risk levels for pedestrians and cyclists when the local street speed limit is 30 km/h. Even with Safe System aligned measures such as safety platforms and roundabouts, drivers and riders can still choose to exceed design speeds. Importantly, the use of all-way stop signs signifies a conscious intent of the road designer to design for Safe System outcomes. Should inadequate levels of driver compliance prove to be the case, strengthening measures can be considered, using for example, small-diameter roundabouts. Appropriately-scaled roundabouts would generally be preferred over four-way stop signs for safety reasons, subject to their potential to impact on land uses and/or surrounding utilities. Where space is constrained all-way stop signs offer a practical alternative. Figure B.3 shows an example from the town of Banff, Canada.

Figure B 3: Four-way stop signs used in a City Street setting in San Francisco, USA

B.1.4 Signalised intersections with 'Scramble' phasing with 30 km/h speed limits (or lower)

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	

Intersection phasing that does not allow vehicle movements while pedestrians are crossing will sharply reduce crash and injury risks when travel speeds are constrained to low levels (i.e., not more than 30 km/h). Assuming that pedestrian and vehicle volumes remain unchanged, there will be no contribution to safety from exposure reduction. 'Scramble' phasing of signals (Figure B.4), which is particularly appropriate for high pedestrian activity areas, achieves this objective when accompanied by infrastructure designed to achieve low travel speeds. Scramble crossings are Safe System-aligned where speeds are already low, but otherwise have the same problems mentioned with standard crossings, if pedestrians cross on a red signal or if drivers run a red signal. While referred to here as 'scramble' crossings, some jurisdictions may be more familiar with the 'Barnes Dance' terminology. Makwasha et al. (2017) reported reductions of around 50% in pedestrian casualty crashes from the use of 'Barnsdance' (i.e., Scramble phasing).

Figure B 4: Scramble crossing (or Barnes Dance), Queen Street, Auckland, New Zealand

Source: Barnes Dance, Queen Street, Auckland, www.greaterauckland.org.nz, Creative Commons Attribution

B.1.5 Restricted access intersection

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓✓

In local streets, cross-road intersections present the greatest concentration of conflict points for vehicular traffic, as well as for pedestrians and cyclists. A design form has been developed to reduce the number of conflicts for all road users, and to create lower risk speeds and conflict angles. A small roundabout or traffic island at local street intersections to require motorists to turn rather than pass through the intersection, while still allowing cyclists (and pedestrians) to pass through. Because motorists are required to turn at a restricted access intersection, vehicle-to-vehicle conflict is effectively eliminated at the intersection and vehicle speeds are reduced to low levels where cyclists and pedestrians negotiate the intersection. In a low-speed setting, such as 30 or 40 km/h, this local street design form is aligned with Safe System principles for both cyclists and pedestrians. The resultant movement restrictions necessitate an impact assessment on access, including emergency services and waste disposal vehicles.

Figure B.5 shows an example of a restricted-access traffic island at a local street intersection in a 50 km/h setting in suburban Sydney.

Figure B 5: Restricted-access intersection of local streets in suburban Sydney

B.1.6 Limit access by mode

Injury Severity	Crash Likelihood	Exposure to Conflicts
		✓✓

With general traffic being of lower priority in City Hubs, the possibility of limiting or even disallowing access to some modes could be considered. The degree to which selected modes might be restricted should be influenced by the M&P values assigned to the City Hub. Making alternative provision for general traffic through, for example, by-pass routes supported by appropriate reallocation of road space and associated signal phasing, has the potential to make a substantial reduction in conflicts that can occur between motorised traffic and vulnerable road users. It can also allow a greater share of existing capacity to be assigned to public transport, pedestrians and cyclists.

Figure B.6 shows George Street Sydney where motor vehicles have been prevented from entering a city street used by light rail, pedestrians and cyclists. If there are no, or few, cars using a particular road or a high-risk section, the potential for conflicts falls accordingly. In the example shown, general vehicle travel is not permitted through highly pedestrianised areas of the light rail route. In this way, high-priority is afforded to pedestrians, especially public transport passengers, while good access is also provided to public transport services, with low-risk space incorporated for cyclists. This form of treatment accords with the aims of City Streets and Places being designed to support “businesses, on-street activity and public life while ensuring excellent connections with the wider transport network”. In City Places there is a desire to meet the high demand for pedestrian activities and lower levels of vehicle movement.

Figure B 6: Restricted access for passenger cars and motorcycles in George Street Sydney

B.1.7 Geo-fencing technology on public transport vehicles

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Low tram and LRV speeds are appropriate within City Hubs from the perspectives of both safety and amenity. To support tram and LRV travel speeds not exceeding 20 km/h within City Hubs, geo-fencing technology for these vehicles could be introduced. While a 30 km/h speed limit would generally be regarded as a low risk travel speed for cyclists and pedestrians, trams are of vastly higher mass and are often designed (unintentionally) with aggressive fronts that are much more threatening to vulnerable road users than are passenger cars. Control of tram travel speeds is an important element of managing vulnerable road user risk in City Hubs, given today's intense focus on maintaining public transport timetables. In this regard, tram drivers have an added safety priority, beyond collisions with vulnerable road users and other vehicles. Tram drivers need to avoid rapid braking that could lead, not only to passenger discomfort but, moreover, to injuries to standing or unrestrained seated passengers if thrown to the floor, or against internal structures or other passengers within the tram. Passengers who are older and/or mobility-impaired, or people using both hands to hold shopping bags, supervise young children, etc., are particularly susceptible to this form of injury.

In summary, trams are of high mass, typically of more aggressive frontal designs, have longer stopping distances than general traffic, and tram drivers must avoid rapid braking, wherever possible, to prevent injury to passengers. The combination of these factors results in higher crash and injury risk to pedestrians and cyclists on a conflicting trajectory. This means that managing tram speeds in busy settings such as City Hubs is vitally important to safety. Geo-fencing appears to offer a low cost means of managing speeds without reliance on error-free performance by tram drivers. Further work may be needed to evaluate its performance in real-world settings and to align tram timetables to this new form of speed management.

B.1.8 Raised signalised intersections with 30 km/h ramps (or lower)

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Traffic signals can be designed and operated to achieve vehicle travel speeds of not more than 30 km/h through the use of raised intersections with appropriate ramp dimensions which promote 30 km/h travel speeds (refer to Figure B.7). In busy pedestrian settings, it may also be appropriate to separate pedestrians and cyclists from all vehicular traffic using signal phases, such as 'Scramble' crossings. There are numerous notable examples of 'Scramble' crossings working successfully across Australasia. Public transport services could receive signal priority over general traffic movement, while the relative priority between public transport, walking and cycling would be influenced by current and future demand, and the desired future state. Some additional benefits due to exposure reduction will accrue if some drivers are diverted to alternative routes. The effects will likely be modest.

Figure B 7: Raised signalised intersection in Devonport Tasmania

B.1.9 Signalised intersections with 30 km/h platforms (or lower)

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Applying the same principles as described above for raised signalised intersections, an alternative means of securing vehicle speeds to low-risk levels involves constructing safety platforms on entry to signalised intersections. Safety platforms have been trialled extensively at both signalised and sign-controlled intersections in the Netherlands. Also, the central area of Gothenburg implemented a mass-action program in its city streets, which brought about a near-halving of pedestrian and cyclist deaths. Some minor additional benefits will result if some drivers are diverted to alternative routes. An example in Paris is shown below in Figure B.8.

Figure B 8: Safety platforms at a signalised intersection in Paris, France

Intersections signals are not aligned with Safe System principles when designed and operated in their conventional form. This is because pedestrians are not always compliant with pedestrian signals and red light running by drivers occurs at speeds that exceed the crashworthiness of the struck vehicle and, in the case of pedestrians and cyclists, far above the biomechanical tolerance limits that define Safe System risk levels (30 km/h). It is also common for pedestrians to be struck by right- or left-turning traffic, and for cyclists riding straight through an intersection to be struck by right-turning motorists.

To overcome this gap between current and Safe System performance, safety platforms or raised intersections have been trialled in the Netherlands (and potentially other countries in Europe). The results of evaluating these trials show that vehicle speeds at the points of conflict can be brought to within the Safe System boundary condition when ramps of an appropriate gradient are used. An example of a successful trial in the Victorian town of Belmont, at the intersection of the Surfcoast Highway and Kidman Avenue is shown in Figure B.9. Some safety benefits due to a reduction in exposure may result from traffic diverting away from intersections with platform treatments to other routes.

Figure B 9: Signalised intersection with 50 km/h safety platforms (Surfcoast Highway/Kidman Avenue, Belmont Victoria)

This safety enhancement to traffic signals operation has demonstrated superior performance in the Province of South Holland, where a 40-50% reduction in injury producing crashes was found when safety platforms were retro-fitted to existing signals (Fortuijn, Carton and Feddes, 2005). While the main purpose for the safety platforms has been to offer better protection to cyclists and to pedestrians when crossing busy, higher speed roads, vehicle occupants have also benefited substantially. To operate intersection signals to achieve Safe System risk levels for pedestrians and cyclists, safety platforms designed to be traversed at around 30-40 km/h may be needed. Further development and trial of design concepts are needed to provide objective evidence on the possible impacts of safety platforms specifically on both pedestrian and cyclist safety, on route efficiency and other issues such as public transport users (bus patrons), stability of heavy vehicles with shifting loads and suitability on stock transport routes.

B.1.10 Raised intersections with 10 or 20 km/h ramps

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓✓	✓

Raised intersections with ramps designed to be traversed at 20 or even 10 km/h, are capable of creating Safe System risk levels for pedestrians and cyclists. These conditions can be achieved with an appropriate degree of vertical deflection. Figure B.10 illustrates this concept at a major roundabout-controlled intersection in the centre of Brussels, Belgium. In addition to the vertical deflection on entry, pedestrians have the benefit of a highlighted cross-walk and a small refuge island to assist in crossing this busy intersection. While the key safety feature of this design is the 10 or 20 km/h ramps, care is needed to ensure clarity of right-of-way between motorists and pedestrians/cyclists, even at low speeds in busy locations. Some minor reductions in exposure may occur if motorists choose to divert to other routes to avoid perceptions of increased delays.

Given the high traffic volumes, signalisation of the roundabout could reasonably be expected to aid operation, while offering the safety benefits of roundabout geometry. Because cyclists are at elevated risk in multi-lane roundabouts, compared with single lane roundabouts, signalisation would likely improve rider safety as well.

Figure B 10: Raised intersection, Brussels, Belgium

B.1.11 Protected cyclist intersections

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓	✓✓	

A protected bicycle intersection is a new type of intersection design for Australasia. It has been used in countries such as the Netherlands, where cycling is very popular and more fully-integrated within the transport system. A protected bicycle intersection includes design elements specifically to reduce crash and injury risk for cyclists negotiating busy intersections. The main elements of the design are:

- a continuous path is provided for cyclists as they approach, move through and depart the intersection
- kerbs are built out, in combination with physical islands on each intersection corner, to increase the separation between cyclists and motorists who are turning, reduce the speeds of turning vehicles and reduce the width of the intersection
- where there are traffic signals, cyclists waiting for a green light are better positioned to be seen more clearly by motorists waiting to turn; this is especially important for the drivers of left-turning trucks whose view of nearby riders is often obstructed
- a few seconds head-start are given to cyclists waiting at traffic signals to help them establish their position within the intersection. In favourable cases, cyclists may be able to cross before the motorists commence their turns
- traffic signals may also be designed to provide separate movements for cyclists to reduce the chance of collisions.

Figure B 11: Signalised protected bicycle intersection in the City of Brisbane, Queensland

Figure B 12: Example of a roundabout with protected bicycle (and pedestrian) facilities (Melbourne suburb of Port Phillip)

Two examples of cyclist (and pedestrian) protected intersections are illustrated in Figures B.11 above and B.12, below. The roundabout design shown in Figure B.12 combines the features of low travel speeds and impact angles, low conflict angles, fewer conflict points and specific design and priority control for pedestrians and cyclists. Overall, this layout aligns well with Safe System principles.

B.1.12 Signalised 'Tennis Ball' intersections with 30 km/h geometry (or lower)

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓	✓✓	

A new design for intersection signals has been trialled at the intersection of Roe Highway and Berkshire Road in the Perth suburb of Forrestfield. The trial consisted of a new geometric layout for an adjacent pair of intersections formed by the creation of a grade-separated intersection with diamond interchange facilities. The basic principle involved using roundabout style islands that allowed turning drivers and riders to follow their normal paths by cutting through gaps in the generally circular island within each intersection. Through-vehicles, which pose the greatest threat to safety, even when vehicles are travelling at legal speeds, are slowed by the roundabout-style geometry and any conflicts are likely to happen at more favourable angles than 90° and at lower speeds. An evaluation of the performance of this new design (Nicholls, 2017) showed that 99% of vehicles passing through the intersection do so at or below the Safe System threshold of 50 km/h. This compares with a normal layout in which only 30% of vehicles pass through at 50 km/h or less. In the two years of its operation, only 4 property damage crashes have been experienced and no fatal or injury producing crashes (Nicholls, 2019).

While the trial involved treating a pair of interchange intersections formed as a result of grade-separation, the 'Tennis Ball' design can be used at individual intersections by applying the principles of reducing the likelihood of vehicles passing through at greater than the appropriate boundary condition speed. In the case of pedestrians and cyclists, the intersection geometry and phasing can be optimised to keep vehicle speeds through the intersection to less than 30 km/h and signal phasing can be designed to maintain time-separation between vehicles and vulnerable road users. Unless travel speeds are compatible with the 30 km/h boundary condition for vulnerable road users, the 'Tennis Ball' cannot be considered Safe System-aligned for pedestrians and cyclists. Figures B.13 and B.14 show the intersection layout from above and from street level, respectively.

Figure B 13: 'Tennis Ball' signalised intersections at Roe Highways / Berkshire Road, Forrestfield, Perth

Figure B 14: ‘Tennis Ball’ signalised intersections at Roe Highways / Berkshire Road, Forrestfield, Perth

B.1.13 Signalised roundabout with separate phases for public transport, cyclists and pedestrians

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓✓	

Roundabouts have proven very successful in safely controlling traffic movements at intersections. The safety features of roundabouts include:

- making it much simpler to choose a safe gap in approaching traffic – the number of major conflict points reduces to four, compared with 32 for a conventional four leg intersection;
- reducing speeds to lower the risk of crashes with intersecting traffic;
- in the event of a crash, minimising injury risk by better matching the crash speeds and angles, with the protection vehicles are capable of providing in a collision.

These safety features combine to reduce the risk of severe injuries by up to 90%. Roundabouts are far safer than most other types of intersection control, including traffic signals, which reduce injury-producing crashes by around 45-50% (Corben et al., 2007). However, in their basic form, they provide modest standard facilities for pedestrians and cyclists. Additional measures are needed. The provision of signalised control of roundabouts allows the safety benefits of lower travel speeds, more favourable conflict angles and a vast reduction in the number of conflict points within the intersection to be realised. While not common, this design form has many advantages in a City Hub setting, including the opportunity to directly control the green time to each road user group, according to the prioritisation plan for City Hubs, and to landscape the roundabout and its approach islands to improve the overall amenity of these busy places.

Signalised roundabouts allow direct control over the modes and individual movements performed at an intersection, while also providing the inherently low risk form of operation needed on high exposure roads, especially when catering for pedestrians and cyclists. Part of the design of a signalised roundabout would be the provision of separate signalised crossing movements for pedestrians and cyclists, as appropriate. The combination of dedicated phases for pedestrians and cyclists, and design speeds of around 30 to 40 km/h for motor vehicles, results in low risk operation, even for unprotected road users.

B.1.14 Grade-separation

Injury Severity	Crash Likelihood	Exposure to Conflicts
	✓✓✓	

In City Hubs, Streets and Places, grade-separation for pedestrians can be designed to create an architecturally-integrated and seamless link between rail and other public transport services, thereby averting the need for many pedestrians to cross wide city streets. Grade-separation doesn't affect severity or exposure (the same numbers of vehicles, and pedestrians and/or cyclists, continue to use the location) but eliminates crash likelihood by eliminating conflict through vertical physical separation and consequently eliminating crash likelihood. Such a facility would create a better modal interchange experience for public transport passengers, as well as improving access to and from city centres and giving higher priority to vehicular through-traffic. Design issues to consider are:

- Minimising/carefully managing level changes, with special attention to mobility-impaired users
- Creating direct links aligned with pedestrian desire lines to maximise likelihood of their use
- Integrating tunnels/overpasses into rail stations and other public transport stops, with potential to provide direct underground connections between all public transport modes
- Integrating connections between rail and other public transport services within a larger commercial development could include, for example, shops, residences, medical rooms and offices
- Ensuring any structures are visually and functionally compatible with the value of place. This may result in well-designed physical connections that are beneath ground or natural extensions of existing buildings, designed to enhance the appearance and feel of the existing settings.

It is acknowledged that grade-separation across roads and streets of high place value may not be appropriate in conventional form. However, many large cities have been successful in building into the surroundings grade separation that forms a natural part of the busy city areas. Some, such as the Devonshire Street tunnel in central Sydney (Figure B.15), lead pedestrians conveniently below or above street level, through shopping and commercial developments, to reach the other side of busy streets with high place value. In areas of high place value, such as City Hubs, Streets and Places, such facilities can include escalators and lifts to facilitate changes in vertical direction and form part of a natural experience in negotiating city streets.

Figure B 15: Grade-separation (tunnel) linking major rails services with City Streets

B.2 Between Intersections

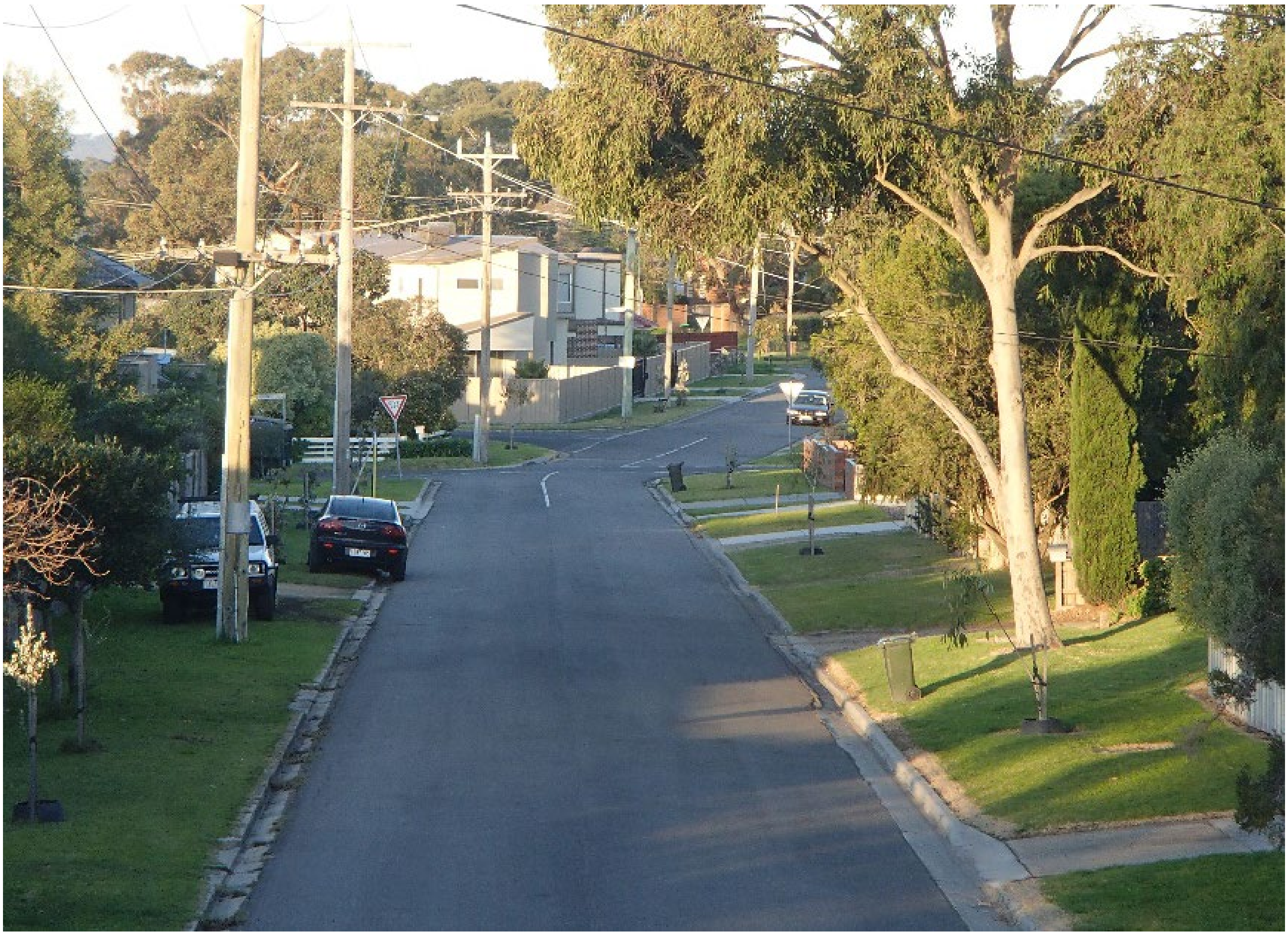
B.2.1 Footpaths

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓	✓✓	✓

Footpaths tend to be taken for granted but are too often not provided in local streets, especially in outer metropolitan areas where new residential subdivisions are being developed (refer to Figure B.16). This happens as a result of a failure by property developers to make even the most basic provision for walking in urban areas. There are a number of important consequences from these long-standing practices. First, pedestrians are forced to walk on roadways when the space normally provided for footpaths is blocked by overgrown trees and other vegetation, parked vehicles or otherwise unsuited for walking because of wet weather and/or poor surfaces. This results in pedestrians, often children on foot and/or parents with young children, prams and strollers, negotiating traffic while walking on the road alongside approaching traffic travelling at 50 km/h or higher. On occasions, pedestrians will have their backs turned and have minimal lateral clearances. Such conditions are far outside the boundaries for low-risk walking and often remain in place for decades due to insufficient funding to rectify the situation. Mobility-impaired people and older and younger pedestrians using local streets become even more vulnerable in these circumstances.

A secondary effect of a lack of basic walking conditions is that people are more inclined to driver, particularly when transporting children to and from school, which adds to the problems of car dependence, human inactivity, congestion around schools and the resultant risks that children face when interacting with traffic.

Figure B 16: Example of a local residential street with no footpaths



B.2.2 30 km/h speed limits or lower

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

While speed behaviour is more strongly influenced by a combination of speed limits and infrastructure design to achieve the set speed limit, it is not always possible to provide the required infrastructure to make the speed limit the natural choice of drivers. However, the simple and inexpensive step of reducing the speed limit serves several important purposes:

- Regardless of whether drivers agree with the limit, many will comply, thereby reducing the average speed of traffic. Lower average speeds substantially reduce the risk of crashes and of severe injuries given a crash. For some motorists, the lowering of a speed limit may divert them to roads more suited to higher speed travel. The net effect of reduced exposure on safety may be small but, nevertheless, worthwhile.
- Introducing a lower limit, based on Safe System principles, allows the responsible road authority to exercise its duty of care to the users of the system. At present, speed limits are commonly set well above low risk levels because speed limit setting practices were established in an era when knowledge on crash and injury risk was unavailable and not as well understood as today.
- Over time, road users will come to accept the lower limit as reasonable, thereby normalising this kind of behaviour, especially in City Hubs, Streets and Places.
- Lower travel speeds support the active travel modes, resulting in long term improvements in population health, greater patronage of public transport services. This in turn leads to reduced congestion, reduced green-house gas emissions and the potential to create a highly attractive environment that is more supportive of roads and streets passing through areas with place value, such as City Hubs, Streets and Places (refer Figure B.17).

In Local Streets, both speed and traffic volumes will affect not only safety but also the amenity of the street and surrounding areas. In these circumstances, it may be appropriate to supplement location-specific treatments with sound traffic management techniques aimed at minimising extraneous traffic in Local Streets. This combination will help to achieve the aims of low risk to pedestrians and cyclists, and support for the active/sustainable transport modes, while creating pleasant and, in some cases, vibrant Local Streets.

Figure B 17: 30 km/h speed limits (Stockholm, Sweden)

B.2.3 Shared use by cyclists of general traffic lanes (with 30 km/h speed limit or lower)

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	

In a 30 km/h setting, cyclists and vehicles sharing the same lane is considered to be aligned with Safe System risk levels. Risks for cyclists under this arrangement include car-dooring, where insufficient clearance space exists, and conflicts between cyclists and drivers parking and un-parking. In City Streets, parking turnover tends to be frequent, which makes this crash type a potential problem. Because cyclists who ride above 30 km/h will be operating outside the boundary condition for Safe System risks, it will be important to ensure speed limit compliance by the operators of all vehicles, including cyclists. Figure B.18 illustrates circumstances in which cyclists are able to share lanes with general traffic at low risk.

In slow streets, that is, 30 km/h or lower, the risks for people cycling or e-scootering (or using other emerging mobility devices) by sharing the general traffic lane will be quite low. However, other risk factors than travel speed alone will affect overall safety levels. The volume and composition of traffic and the presence of parked vehicles also influence risk. Where vehicle volumes are high, and/or there are significant volumes of large vehicles (e.g., trams, buses or trucks) and/or parked cars, risk levels for cyclists and pedestrians rise.

Figure B 18: Example of shared-use cyclists and general traffic lane, integrated with roundabout and wombat crossings (Church Street, Brighton, Victoria)

B.2.4 Playground zones

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

The City of Edmonton in Alberta, Canada, has introduced the concept of Playground Zones for use in neighbourhood streets. This form of treatment entails a 30 km/h speed limit to operate daily, from 7.30 am to 9.00 pm, in the vicinity of parks, playgrounds and schools. Having nominated itself as a Vision Zero City, this Edmonton initiative aims to eliminate the risk of children being harmed in traffic along neighbourhood streets. Figure B.19 shows an example of the Playground Zone concept in the Edmonton suburb of Strathcona, where it has been combined with a separated cycle lane. Because of the 30 km/h speed limit, the design is considered to align with Safe System risk levels. If experience were to show that drivers do not comply with the limit, additional physical measures, such as vertical deflections, may be needed to secure low risk speeds. The City of Edmonton supports its neighbourhood safety measures with speed indicator displays and associated enforcement and educational activities.

Figure B 19: Playground zone (30 km/h speed limit), used in combination with segregated cycle lane (Strathcona, Edmonton Canada)

B.2.5 On-road cycle lanes (30 km/h speed limit or lower)

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Low-risk cycling on local streets can be achieved in several ways. Physical separation is the most effective though not always feasible in narrow streets where vehicular access is also required. Some local streets were designed with generous widths, allowing the retro-fitting of separated cyclist paths to the street cross section, and leaving adequate, though potentially restricted, widths for motorists (refer Figure B.20 below).

There are two main forms of on-road cycle lane suitable for use in local streets:

- Ideally, the cycle lane would have an adequate clearance distance between the cycle lane and parked cars, to avoid car doors being inadvertently opened into the path of the cyclist;
- Where an adequate clearance distance cannot be provided (and on-street parking cannot be removed), speed limits should not exceed 30 km/h to help ensure cyclists do not impact car doors above this speed. An impact between a cyclist and a car door at 30 km/h is still severe and could result in a fatal outcome, especially if the cyclist were to fall and be run over by following traffic.

By reducing the speed limit to 30 km/h along local streets, cyclists can be permitted to share the general traffic lane, while still meeting Safe System principles.

An innovative example of a local street cycle lane is shown in Figure B.20 whereby two-way cycling is permitted on a street that is restricted to one-way for general traffic. On-street parking has been confined to one side of the street, thereby allowing cyclists to use the general traffic lane when heading in the same direction and to use the cycle lane when heading in the opposite direction to general traffic. The risk of car-dooring incidents is low in this design layout.

Figure B 20: Two-way on-street cycle facilities on a one-way street (Strathcona, Edmonton)

B.2.6 Wombat crossings (30 km/h or lower platforms)

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

The use of wombat crossings in Local Streets can provide Safe System aligned treatments for pedestrians. They would normally be best used at locations with a higher crossing demand and where pedestrians may be at heightened risk, such as at schools, shops, parks, aged care or community facilities and public transport stops or stations. When used in combination with 40 km/h speed limits, or lower, it is deemed that Safe System requirements for pedestrians would be met. Some reduction in exposure may also be experienced if a proportion of motorists choose alternative routes to avoid the perception of delays caused by wombat crossings.

An example of such a wombat crossing is shown in Figure B.21, below. This crossing, which is situated within an area-wide 40 km/h speed zone, assists pedestrians in general to cross Darling Street in Rozelle, Sydney, while offering the added advantage of providing public transport users with low risk access to and from the nearby bus stop. In this instance, cyclists share the traffic lane with general traffic. An alternative design can be utilised by taking cyclists inside the kerb extension to minimise conflict between vehicles and cyclists where the roadway narrows at the kerb blister/refuge island. While this arrangement allows riders to position themselves clear of the car-dooring zone, riders are exposed to risks that are outside the Safe System boundary where 40 km/h speed limits apply.

Figure B 21: Local Street wombat crossing, in combination with a pedestrian refuge and a kerb blister, set in a 40 km/h area-wide speed zone (Darling Street Rozelle, Sydney)

B.2.7 Zebra crossings (with 30 km/h speed limits or lower)

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓	✓

The safety performance of zebra crossings can be enhanced by kerb blisters, which help to ensure good sight lines between drivers and pedestrians, and reduce the crossing distance and hence the time spent by pedestrians exposed to crash risk while crossing. A zebra crossing located in a 40 km/h speed zone or higher does not deliver low-risk operation. With a safety platform, a zebra crossing becomes a wombat crossing and takes on a substantially lower fatal or serious injuries risk profile. This is because approach speeds are reduced, allowing motorists and pedestrians more time to avoid potential conflicts. Makwasha et al. (2017) reported reductions of around 75% in pedestrian casualty crashes from zebra crossings but lower reductions for pedestrian serious injury crashes (only 40% c.f. 70% for wombat crossings).

Figure B.22 below shows the potential to include public seating, street plantings and cycle parking into the space created by kerb blisters or outstands. This clearly adds to the quality of place as well as delivering safety and convenience for pedestrians. Some design forms facilitate the reallocation of road space, thereby presenting valuable opportunities to improve the amenity and vibrancy of roads and streets. These opportunities can make important contributions to place-making and strengthen the overall value of Place.

Figure B 22: Kerb blisters and zebra crossing (which can include provision for seating, cycle parking and street beautification)

B.2.8 Kerb blisters or road narrowing

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓	✓✓	✓

Reducing the width of roadway to be crossed by pedestrians reduces the time spent by the pedestrian exposed to direct crash risk. Further, the narrower roadway makes gap selection safer, especially when the traffic approaches from one direction only and the speed limit is 30 km/h. The example shown (Figure B.23) for a city street in London illustrates this form of design, with safety platforms also integrated within the design. This combination of features is considered to be aligned with Safe System risk levels. In this particular case, parking is allowed close to the crossing location, which tends to restrict sight lines between approaching motorists and crossing pedestrians. However, the low travel speeds elicited by this treatment help to overcome risks due to limited sight lines. In situations where children are crossing, such as at schools or near playgrounds in Local Streets, extended sight lines are desirable to overcome added risks due to their shorter stature and unpredictable behaviour. Makwasha et al. (2017) reported reductions of around 30% in pedestrian casualty crashes from kerb blisters/extensions.

Figure B 23: Kerb blisters with safety platforms in a 20 mph city street in London

B.2.9 Speed platforms

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Speed platforms which have been designed to achieve travel speeds of 30 km/h or lower can be regarded as creating Safe System conditions for pedestrians and cyclists crossing or riding within the range of influence of the platform. Speed platforms can be constructed along local streets and, potentially, along suitable Activity Streets and Boulevards, at separation distances and locations that optimise speed behaviour across a network of local streets or along a pedestrian- and/or cyclist-oriented route (refer Figure B.24 for an example). The main mechanism of effect is via crash likelihood and injury risk reductions but, in some cases, a modest-scale benefit due to exposure reduction may occur as a result of motorists choosing to use roads perceived as allowing higher travel speeds.

Optimising placement to gain the desired effect along a local street or across a network of local streets is challenging but highly desirable. Further applied research could assist in refining the process of spatial optimisation. Speed platforms located near and on the approaches to the intersections of local streets have the added advantage of addressing severe injury risk where conflict is most highly concentrated and the risk of severe injury in a 90° vehicle-to-vehicle crash is at its highest. Cyclists and pedestrians will each benefit from these measures when negotiating intersections. While not strictly traffic-calming in the conventional definition of the technique, Makwasha et al. (2017) reported reductions of around 70% in pedestrian death and serious injury crashes from the use of traffic-calming measures; speed platforms and other speed moderating design elements form the core of the traffic-calming philosophy.

Figure B 24: A series of speed platforms in a local street in a Melbourne suburb

B.2.10 Horizontal deflection

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓	✓✓	✓

Another way of achieving vehicle travel speeds aligned with Safe System risk levels (i.e., 30 km/h or lower) is through changes in horizontal alignment. A variety of geometric designs can be utilised to affect reductions in travel speed below the 50 km/h default, by requiring vehicles to undertake a lateral movement when proceeding along a street. Vertical deflection, using speed platforms, is generally regarded as more effective than horizontal deflection, however, vertical deflection may not suit all situations. Because the effect on travel speed does not necessarily extend beyond a range of influence, these measures may need to be repeated along a route or across an area to have the desired spatial coverage. Figure B.25 shows an example of one of many forms of changed horizontal alignment that achieve lower risk travel speeds.

Figure B 25: Example of horizontal deflection in a local street in a Melbourne suburb

B.2.11 Road narrowing

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Figure B.26 below shows a Swedish example where the road has been narrowed to one lane at the location of a bus stop on a local street. The purpose of the narrowing is to prevent any other vehicle movements while passengers are boarding or alighting from the bus. In this way, bus passengers – school children and older or mobility-impaired people, in particular – are not at risk of being struck by cars overtaking the bus during the boarding/alighting stage. The delays to individual motorists are minimal and in aggregate insignificant on a network-wide scale. This form of safety measure can be used more generally to support lower travel speeds in local streets and reduce the potential for rat-running by motorists with no destination within the local streets system.

Figure B 26: Road narrowing at local streets bus stop in Sweden to prevent overtaking by general traffic

Source: Dr Johan Strandroth

B.2.12 Textured or coloured road pavements

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓	✓✓	

Changes in the colour and/or texture of road pavements offers another means by which to bring about low risk conditions for pedestrians and cyclists. While coloured surfaces can help to encourage drivers and riders to travel at a lower speeds and also to highlight the presence of areas of potential conflict, coloured surfacing should not be regarded as providing Safe System risk levels on its own. By combining it with lower speed limits, for example 30 km/h, Safe System alignment becomes a reality.

Changes in surface texture can be more effective than changes in colour, particularly if the texture is quite coarse or rough to traverse in a car, truck or motorcycle. Surface roughness can, however, present difficulties for cyclists. To a degree, these problems can be overcome by providing a smooth surface for cyclists, but a textured surface for motor vehicles.

An example of the use of both surface texture and colour, in combination with horizontal deflection and kerb outstands, is shown in Figure B.27, below.

Figure B 27: Surface texture and colour, used in combination with horizontal deflection and kerb outstands (Melbourne suburb of South Yarra)

B.2.13 Shared zones

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

While less commonly used than other measures, shared zones in Local Streets delivers Safe System risk levels by virtue of the 10 km/h speed limit and the physical design to make low travel speeds by drivers and riders a more natural choice. In some jurisdictions (e.g., the ACT), 20 km/h speed limits may apply in shared zones. Changes to pavement colour and/or texture are a desirable feature of shared zones. Shared zone designs are particularly suited to streets where kindergartens and schools, especially for primary age children, and parks and playgrounds are provided, in shopping centre car parks and for other places where people gather for a purpose. Not only do pedestrians enjoy reduced risk compared with today's basic local street design, but so too do cyclists. The nature of cycling may be different in Local Streets when compared with other settings, such as along Movement Corridors and Connectors. A greater proportion of riding along Local Streets will have a local destination than in some other M&P settings. Shared zones enhance the quality of the surroundings and support the sense of Place in Local Streets.

Significant numbers of cyclists travel comfortably at over 10 km/h. Shared zones (with 10 km/h speed limits) will likely experience riding above the speed limit unless high numbers of pedestrians are present, or other provisions are made to address cyclist speeds. Surfaces that discourage incompatible cyclist speeds, while still meeting the fundamental objectives of creating a safe and aesthetic environment could be incorporated.

Figure B.28 below shows how a shared zone has been introduced to a local street in Mornington, Victoria, to support safe access to and from car parking accessed via Local Streets. The design shown combines changes to surface texture and colour, horizontal deflection, narrowing and enhancements to aesthetics, through new street plantings and furniture.

The early experience with the design and use of the shared space concept took place in the Netherlands. The 'woonerf', or 'living-street', was designed specifically to create safe and attractive places where people live or visit simply to spend time. Woonerven are well-suited to use in Local Streets and the squares of towns and suburbs. A well-designed woonerf doesn't need a speed limit; the concept of the woonerf relies on its unique combination of design features and the *absence* of traffic signs, signals and markings to require all road users to cooperate in a low speed environment to move successfully through the shared space.

Figure B 28: Local Street shared space (10 km/h) together with speed platform, horizontal deflection and street plantings (Mornington, Victoria)

Figure B.29 shows a shared space setting in a city street in Raleigh, North Carolina. The space is uniformly at footpath level and paved with materials not normally provided for vehicles use. Contrasting pavers and transverse patterns create a different feeling for all road users, particularly drivers and riders who are normally presented with strong longitudinal visual cues, through features such as level differences and differing surfaces, delineated by kerbs and drainage channels. Shared space does not define streets in this way, preferring to convey to drivers and cyclists they are entering space primarily provided for pedestrians.

Figure B 29: Shared space in a city street in Raleigh, North Carolina

B.2.14 Fully segregated pedestrian paths

Injury Severity	Crash Likelihood	Exposure to conflicts
	✓✓✓	

The provision of footpaths in City Hubs, Streets and Places is normal practice and would be expected to be appropriate into the future. Wider footpaths are clearly more appropriate in places where walking is to be prioritised. To further strengthen the safety effects of wider footpaths, kerb blisters can be used to shorten crossing distances for pedestrians and so require them to spend less time on the road, exposed to crash risk. Kerb blisters also improve sight lines between drivers and motorists, make gap selection easier for pedestrians, and have the added benefit of inducing lower travel speeds among motorists, which further reduces crash and injury risk to pedestrians and cyclists. Kerb blisters are regarded as Safe System aligned when located within a 30 km/h speed limit.

Many local streets across urban areas of Australasia do not have formed footpaths. This results in residents and visitors to these streets having to walk on roads, especially during and after wet weather when unpaved surfaces become wet or muddy. In these locations, lower speed limits should apply. From a safety perspective, travel speeds of not more than 30 km/h represent low risk but 40 km/h should be supported where approval to 30 km/h cannot be gained. Makwasha et al. (2017) reported reductions of around 90% in pedestrian death and serious injury crashes from the provision of footpaths or shoulder provision.

B.2.15 Separated cycle facilities

Injury Severity	Crash Likelihood	Exposure to Conflicts
	✓✓✓	

Separation of cycling from vehicular traffic is potentially appropriate in City Hubs, Streets and Places, as well as various other M&P families where cycling is a prioritised mode of travel. Separated cycle facilities can take a number of forms, depending on the legal designation of the facility, available space and other requirements at the specific location. Neither exposure nor injury severity are altered significantly by separated cycle facilities, however, crash likelihood falls markedly.

While separation is, by definition, highly effective in eliminating conflict, there will be places where cyclists come into conflict with vehicles and/or pedestrians. These locations of conflict must be managed to ensure low risk speeds by vehicles and also by cyclists where the conflicts involve pedestrians. Separate cyclist phases at traffic signals can aid with separation. Figure B.30 captures a recently opened example from Auckland waterfront area of the city. The provision of minimum widths of cycle lanes is important in assuring safety along two-way cycle facilities to limit the potential for head-on collisions between riders and to allow faster riders to overtake at low risk.

Figure B 30: Separated Cycle Facility, Auckland

Source: Photo courtesy of Auckland Transport

For cyclists travelling along Movement Corridors and Connectors with speed limits above 30 km/h, it will be necessary under a Safe System approach to provide segregated cycle paths. This entails full separation of cyclists from motor traffic. Because this class of road typically has speed limits of 60 km/h or higher segregation from traffic for the safety of riders is imperative. Figure B.31 shows an example of a shared path (shared with pedestrians) alongside a 60 km/h Movement Corridor Connector road. The form of segregation in this instance is quite limited in that it is achieved using kerbing to create a level difference. Where lateral separation of cycle facilities from vehicular traffic is limited and speed limits are high, more effective physical separation should be considered, while avoiding the creation of hazards to motorists whose vehicles may strike the barriers. This is especially pertinent on curvilinear road alignments, as show in Figure B.31.

Figure B 31: Shared path in a Melbourne Bayside suburb

Where segregated cycle paths intersect with low volumes side-roads and similar (e.g., car-park access roads), priority crossings should be provided to assign right-of-way to the cyclist and to slow the speeds of approaching motorists. Figure B.32 illustrates how a platform design has been used to secure the speeds of vehicle to low risk levels.

Figure B 32: Speed platform to moderate vehicle speeds where cycle paths meet minor side-streets and car-park access roads

Where 40 km/h speed limits apply, cyclists can be accommodated at low risk levels through the use of on-road cycle lanes (no physical barrier) designed to include adequate clearance widths between the cycle lane and the opened doors of parked vehicles. Guidance on appropriate clearance widths can be drawn from the Amy Gillett Foundation's campaign, 'A Metre Matters' campaign, subsequently adopted as law in some Australasian jurisdictions. While not developed specifically to apply to cycle lane design standards, this new cycling regulation, which aims to raise awareness and enforce the practice of requiring drivers to adopt a minimum clearance of one metre when passing a cyclist in an urban setting, indicates the minimum separation that cyclists are likely to expect. Figure B.33 shows an on-road cycle lane in Melbourne, with clearance between cyclists and parked cars.

Figure B 33: Bicycle lane with adequate clearance to opened car doors – Melbourne suburb of Carlton

Source: Photo courtesy of Phil Gray, SSRIP Team, DoT, Victoria

B.2.16 Pedestrian operated signals, zebras or wombats in 30 km/h (or lower) speed limits

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓✓✓	✓✓	✓

Pedestrian operated signals, and zebra and wombat crossings provide a high level of protection to crossing pedestrians, where the designs are accompanied by speed platforms aimed at travel speeds of 30 km/h or below (refer to Figure B.34). In some circumstances, such as along tram or light rail routes, provision of platforms that meet these speed requirements may be difficult. In these circumstances, it is highly desirable that the speed limit be set to 30 km/h (or less) and infrastructure measures to secure such speeds are also provided where practical. Space can often be provided for on-road cycle lanes which are deemed to be Safe System aligned when the speed setting is effectively at or below 30 km/h. Makwasha et al. (2017) reported reductions of around 25% in pedestrian casualty crashes from the use of pedestrian operated signals.

Figure B 34: Wombat crossing (City of Port Phillip, Melbourne)

B.2.17 Car-free streets

Injury Severity	Crash Likelihood	Exposure to Conflicts
		✓✓✓

The creation of car-free streets is highly effective as it eliminates the exposure of vulnerable road users to crash risk. While car-free streets could be viewed as the same as, or a subset of, the 'limit access by mode' treatment form, they have been described separately in this report because of their growing prominence as measure for selected streets in busy cities. Creating car-free streets or limiting access by mode will be designed differently, depending on the mode/s permitted along a given street.

If the movement value assigned to general traffic in a City Hub, Street or Place is low and the value assigned to public transport, walking or cycling is high, it may be appropriate to consider introducing a car-free street, subject to an assessment of the network-wide effects of diverting traffic to alternative routes. Car-free streets in M&P settings will not be appropriate where the Movement value for general traffic is high unless, of course, it is desired to eliminate cars in the longer term.

Some exceptions to the car-free status of a street may exist where goods and services vehicles are allowed entry under restricted conditions. An important strategy is to limit access of such vehicles to low exposure periods (e.g., midnight to 5am and/or on weekends). However, given that City Hubs, Streets and Places typically attract large numbers of people to night-time entertainment, often leading to alcohol and/or drug use, consideration should be given to these heightened aspects of risk when determining the conditions under which vehicle access is granted.

Good practice, aligned with Safe System principles, would ensure that trams operating in car-free streets would be restricted to low speeds, typically not more than 10 km/h. There is limited experience and/or evaluations in Australasia with this scenario, so being definitive about operating speeds may be premature. The threat of a severe injury to a pedestrian or cyclist struck by a tram is high, not only because of the dramatic difference in mass, but also the frontal design of much of today's fleet. Trams with fronts designed to absorb impact energy and prevent a struck pedestrian or cyclist being dragged under the tram should be part of the long-term plan for assuring Safe System conditions where trams and vulnerable road users share the same space. As noted in the section on the earlier fitment of geo-fencing to trams, tram drivers have the added requirement to avoid high levels of deceleration because they place on-board passengers at risk of falls and other impact-related injuries, as well as causing considerable ride-discomfort to passengers.

Another consideration in introducing 10 km/h speed limits for trams operating in car-free streets is the potential to convey incorrectly the impression to pedestrians and cyclists that the street operates under shared space conditions. It is understood that the new light rail system being introduced to Sydney will operate with a 20 km/h speed limit to underline the fact that George Street is not a shared space. While average speeds of light rail vehicles are expected to be substantially lower than 20 km/h during busy periods (i.e., periods of high exposure to risk), the safety performance will be carefully monitored and evaluated to ensure that risk levels are low and aligned with Safe System expectations. Figure B.35 shows how George Street looks after the commencement of Sydney's light rail project.

Figure B 35: Car-free streets with light rail, George Street, Sydney.

Image courtesy of City and South East Light Rail (CSELR))

B.2.18 Exposure reduction/redirection of through-traffic

Injury Severity	Crash Likelihood	Exposure to Conflicts
		✓✓

Another means of reducing crash risk to Safe System levels is to reduce exposure to crashes with motorised traffic. If there are no, or few, cars using a particular road or a high-risk section, crash risk falls to low levels. In the example shown from Huitsfelds gate in the city of Oslo (Figure B.36, below), cars and motorcycles are not permitted for a 40m section of a busy tram route. In this way, high-priority is afforded to pedestrians, especially public transport passengers, and good access is provided to public transport services, with low-risk space incorporated for cyclists. This form of treatment accords with the aims of City Streets being designed to support “businesses, on-street activity and public life while ensuring excellent connections with the wider transport network”.

Figure B 36: Restricted access for passenger cars and motorcycles (Oslo, Norway)

B.2.19 Medians

Injury Severity	Crash Likelihood	Exposure to Conflicts
✓	✓✓	

In busy Activity Streets and Boulevards, medians (and pedestrian refuges) can be constructed to assist pedestrians to simplify the gap selection task by breaking their crossing manoeuvre into two stages, thereby allowing pedestrians to wait in relative safety in the median (subject to median width) for a safe gap in the second direction of traffic. Medians do not, in general, change the exposure levels (i.e., change pedestrian or vehicle numbers) so no assignment of safety gains has been made for the ‘exposure to conflicts’ criterion. As can be seen in Figure B.37, medians can also add visual appeal to an Activity Street or Boulevard, by allowing street-tree planting and other vegetation, and providing space for public seating and other features to enhance the functionality and appeal of the surroundings. The planting of street trees and other vegetation must not compromise sight lines, a problem that can arise gradually as street vegetation matures.

Such enhancements encourage people to enjoy the ‘place’ aspect of a street, as well as shopping and other services in the area. Figure B.39 illustrates the provision of bicycle parking within the median. Where pedestrian crossing movements are clearly concentrated, zebra or wombat crossings can be integrated into the overall median design. In a 30 km/h environment, medians provide Safe System risk levels for pedestrians crossing between formal crossing facilities. Makwasha et al. (2017) reported reductions of around 45-55% in pedestrian casualty crashes from pedestrian refuges, and flush or raised medians.

Figure B 37: Medians reduce the risk of pedestrian crashes (note scope for tree planting and public seating, subject to adequate median width)

B.2.20 Relocation of tram stops from centre of the road to the roadside

Injury Severity	Crash Likelihood	Exposure to Conflicts
	✓✓	

While only some Australasian cities currently have trams or light rail systems, there is a move towards their re-establishment across other Australasian cities. This aligns with the long-term goal of creating sustainable cities and urban areas. Locating tram stops at the kerbside rather than in the centre of the road will reduce crash likelihood by eliminating the need for all pedestrians to cross at least one direction of travel to reach a centre-of-the-road stop (Figure B.38). Injury severity and exposure to conflicts will be unaffected as speeds and volumes will be largely unchanged. Reducing crash likelihood can be a highly effective, especially when people take undue risks while hurrying to catch their soon-to-depart tram. While not a direct translation of the effectiveness of this treatment, Makwasha et al. (2017) reported reductions of over 80% in pedestrian casualty crashes and pedestrian death and serious injury crashes from the use of raised tram stops.

Figure B 38: Kerbside tram stop (one-direction only) in Oslo, Norway

B.2.21 Pedestrian malls

Injury Severity	Crash Likelihood	Exposure to Conflicts
		✓✓✓

As with car-free streets, creating pedestrian malls (refer to Figure B.39, below) all but eliminates risk to pedestrians. However, given the likely high volumes of pedestrians in a mall, the desirability of permitting cycling should be carefully assessed in terms of the risks of conflict between pedestrians and cyclists. Some riders are inclined to ride at high speeds despite the prevalence of pedestrians. In these circumstances, older pedestrians and small children will be at heightened risk. If trams are to operate in pedestrian malls, it is critical that tram speeds be managed to low risk levels and trams are designed to absorb crash energy successfully and eliminate the risk of pedestrians or cyclist being dragged under the tram. The appropriateness of introducing pedestrian malls to City Hubs will depend heavily on the M&P values of the particular City Hub. If general traffic is to be prioritised in a City Hub, a car-free street will not support the intended movement function.

Figure B 39: Pedestrian mall (Vancouver, Canada)

B.2.22 Grade-separation of pedestrians and cyclists from vehicular traffic

Injury Severity	Crash Likelihood	Exposure to Conflicts
	✓✓✓	

In simple safety terms, the most effective form of separation for pedestrians needing to cross Movement Corridors and Connectors is to provide pedestrian bridges, elevated roadways or tunnels. This allows road crossings to be undertaken without the risk of collisions and traffic to move with fewer interruptions to flow. Because vehicle speeds and volumes remain essentially unchanged, the main mechanism of effect is through major reductions in crash likelihood. While very good examples of grade-separation for pedestrians exist, they may impact negatively on surrounding urban space and sometimes require pedestrians to undertake inconvenient diversions to their journeys or take a path that may also threaten personal security. Over the length of many Movement Corridors and Connectors, it will be impractical to provide good coverage for pedestrians, other than at a relatively small number of locations.

Figures B.40 and B.41 show a grade-separated facility for pedestrians and cyclists wishing to cross a Movement Corridor/Connectors in San Francisco and Wellington, respectively. For cyclists and pedestrians, it is important to ensure there are good walking and riding connections to grade-separated facilities. Such facilities should also be close to pedestrian and/or cyclist desire lines to successfully meet their needs. Makwasha et al. (2017) reported reductions of around 70% in pedestrian casualty crashes and 60% in pedestrian fatal and serious injury crashes from grade-separation.

Figure B 40: Grade-separation for pedestrians and cyclists linking multi-level parking with high activity land uses (San Francisco tourist precinct)

Figure B 41: Grade-separation for pedestrians and cyclists on a Movement Corridor/Connector Road (Wellington Waterfront, New Zealand)

Source: Photo courtesy of Iain McAuley, NZTA

Austroads

Level 9, 287 Elizabeth Street
Sydney NSW 2000 Australia

Phone: +61 2 8265 3300

austroads@austroads.com.au
www.austroads.com.au