Active and public transport infrastructure: a public health perspective

A literature review prepared for,
the Protection Team, Community & Public Health
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Executive summary

Introduction
The purpose of this report is to provide public health unit staff, planners and decision makers with an overview of transport planning principles and a summary of the key infrastructure initiatives (and their application, including retrofitting) that help to provide a safe, healthy and efficient active and public transport network.

Background
Over the past few decades, transport policy has focussed on providing road based infrastructure that is faster, wider and more efficient. These policies facilitate driving faster but they also tend to neglect the human impact of crashes, the degraded conditions for walking and cycling, and neighbourhood liveability. Despite these negative consequences, road traffic policy still tends to be predominantly car-centric by design (at least in developed countries). However, there are growing concerns across sectors about health, climate change, and other issues of sustainability. The historic emphasis on a supply-oriented expansion of the transport infrastructure is, arguably, no longer tenable.

Methods
This report lists, categorises, describes and outlines the relative merit and preferred active transport and public transport infrastructure options that can be applied to different road types (excludes national and regional roads) — drawing on evidence and examples from a range of existing international and New Zealand design guidelines. This review is limited to environmental-level interventions (infrastructure) for active and public transport and is primarily concerned with the safety of active transport commuters not car drivers and the ‘level of service’ (the perceived quality of the transport experience) afforded to users of the active transport modes. The review excluded regulatory interventions (e.g. speed limits and give-way rules), media and social marketing campaigns, cycling skills training or other education programmes. The review also excluded the planning and provision of whole networks and other interventions such as school travel plans and community projects. Consideration has been given to any factors that might be especially relevant to the New Zealand context, and local examples have been used where relevant/possible.

Conclusions
Commuter behaviour (mode choice) is heavily influenced by the type and perceived quality of infrastructure that users encounter on a trip-by-trip basis. The quality of active transport infrastructure directly influences safety (and perceptions of safety) and the overall ‘level of service’ afforded to pedestrians, and in particular cyclists. Level of service is strongly related to the likelihood that a person will use a particular mode of commuting.

However, selecting the type, level and quality of new public and active transport infrastructure is always likely to involve debate among stakeholders regarding multiple competing issues. These issues may include considerations around: transport and community, transport and environmental objectives, as well as technical, financial, safety and organisational factors. Transport decisions are also, at least in part, ideological in nature, and they represent differing views of the ‘proper’ distribution of costs and benefits across stakeholder groups (e.g. business owners, home owners, school children, the employed, the unemployed, environmentalists). Key themes in transport infrastructure planning debates often reflect
differing views on transport projects versus other community objectives as well as differing views on the relative merits of investing in private versus public modes.

Nevertheless, ever increasing traffic congestion threatens the ‘ideal’ that motor vehicle users can enjoy both fast access across and out of town, and a quiet neighbourhood in which to live. Increasingly, traffic congestion is forcing a rethinking of much of what transport planners have done previously. Contemporary traffic planning is now giving greater consideration to the ‘link’ and ‘place’ functions of streets, the impact of network design, the ‘liveability’ of streets (including quality of life) and to enabling sustainable transport choices.
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Glossary

Access roads: This is often where your journey starts and ends. These roads provide access and connectivity to many of your daily journeys (home, school, farm, forestry etc). They also provide access to the wider network. Access roads support the active transport modes and may provide for significant numbers of pedestrians and cyclists (urban peak) or be part of identified cycling or walking network.

Advanced stop box: An area in front of a general traffic lane on an approach to a signalised intersection to raise awareness of cyclists by motorists and to give priority to cyclists over other traffic for a particular manoeuvre.

Advanced stop line: A lane limit line for a cycle lane that is extended beyond the limit lines of other adjacent lanes on an approach to a signalised intersection.

Arterial roads: These roads make a significant contribution to social and economic wellbeing, linking regionally significant places, industries, ports or airports. They may be the only route available to important places in a region, performing a ‘lifeline’ function. Arterial roads support the active transport modes and may provide for significant numbers of pedestrians and cyclists (urban peak) or be part of identified cycling or walking network.

At-grade: Where two or more routes meet at the same vertical level.

Barrier: A physical barrier to prevent vehicles that leave the roadway from entering pedestrian areas.

Bicycle: The word “cycle” is recognised in New Zealand legislation.

Bicycle Path: See “exclusive cycle path” below.

Blended crossing: A crossing of the kerb where the roadway and the footpath are at the same level.

Clear zone: An area alongside a roadway, free of potential hazards that are not frangible or breakaway.

Cognitively impaired pedestrian: A pedestrian whose ability to negotiate the walking environment is hampered by a learning difficulty, such as difficulty in reading signs.

Contra-flow cycle lane: A cycle lane on a one-way street allowing cyclists to travel against the flow of other traffic.

Collector road: A non-arterial road that links local roads to the arterial road network, as well as serving neighbouring property.

Crossfall: The slope of the footpath perpendicular to the direction of travel.

Crossing point: Any point on the road network that has been designed to assist pedestrians to cross the roadway.

Crossing sight distance: The distance over which pedestrians must see approaching traffic to be able to judge a safe gap.

Cut-through: A section of a traffic island or raised median where the height has been reduced to the level of the roadway to facilitate pedestrian access between the footpath and roadway, at a kerb ramp face.

Cycle: The word “bicycle” and “cycle” are considered to be synonymous in this document.

Cycle lane: A lane designated generally for the exclusive use of cyclists, except that motor vehicle drivers may use the lane in certain circumstances such as to access parking or to turn at intersections or driveways, for example.

Cycle path: A path that is within the road reserve that is physically separated from the roadway (including cycle track formed under section 332 of the Local Government Act 1974) that is intended for the use of cyclists, but which may also be used by pedestrians. It may not be necessarily within the road reserve (such as in a park or alongside a river, lake or railway line).

Desire line: A straight line between the origin and the destination of a potential pedestrian trip.

Downstream: The direction along a roadway towards which the vehicle flow under consideration is moving.

Driveway: A passageway across the footpath for motor vehicles, which enables drivers to access private property adjacent to the road.

Exclusive bicycle lane: See “cycle lane”.

Expressway: The State Highway Geometric Design Manual defines “expressway” as “a road mainly for through traffic usually dual carriageway with full or partial control of access. Intersections are generally grade separated”.

Exclusive cycle path: A path or path section intended for the exclusive use of cyclists (see GTEP Part 14 Section 6.6.3 Exclusive Bicycle Paths).

Footpath: The part of road or other public place built and laid out for pedestrian use.

Frangible: Designed to break away or deform when struck by a motor vehicle, in order to minimise injuries to occupants.

Frontage zone: The part of the footpath that pedestrians tend not to enter, next to adjoining land or on the opposite side to the roadway.

GIS: ‘Geographic Information System’ – a computerised system used for storing, retrieving, manipulating, analysing and producing geographic data, which is referenced by map co-ordinates.

Grade separation: The separation of pedestrians from other road users by a difference in heights, usually by use of an overpass or an underpass.

Gradient: The slope parallel to the direction of travel.

Headway: In transit operations, the time between vehicles past a given point, usually measured in minutes.

Home zone: See Shared zone.

Kea crossing: A school pedestrian crossing point that is not marked as a pedestrian zebra crossing, at which a school patrol operates.

Kerb: A raised border of rigid material formed between the roadway and the footpath.

Kerb crossing: A place designed to facilitate convenient pedestrian access between the footpath and roadway, at a kerb ramp or, if at the same level, at a blended kerb crossing.

Kerb extension: A localised widening of the footpath at an intersection or mid-block, which extends the footpath into and across parking lanes to the edge of the traffic lane.

Kerb ramp: A localised area where part of the footpath is lowered to the same level as the roadway next to it to facilitate convenient entry to the roadway.

Kerb zone: The part of the footpath next to the roadway.

Landing: A flat area at the top or bottom of a ramp.

Latent demand: The amount of walking that would happen if conditions were improved, but which is not happening currently.

Level of service: The perceived quality of the transport experience.

Living streets: A way to design and allocate road space to give priority to living and community interaction.

Local authority: A regional or territorial authority responsible for local government.

Local road: A road or street used mainly for access to neighbouring properties with little through traffic.

Median: A continuous painted or raised strip along the centre of the roadway.

Mid-block pedestrian signals: Traffic signals that are not at intersections, which stop traffic to permit pedestrians to cross the roadway.

Mobility impaired pedestrian: A pedestrian whose ability to walk is hampered by a temporary or permanent loss of ability. It includes those using mobility aids, those carrying difficult parcels or accompanying small children, and those with temporary conditions such as a broken limb.
Population and economic sites. They may be the only route or not and places to which the pedestrian can recover from their exertions. Legally roads include beaches which pedestrians can use to walk by direct routes to their desired destinations.

**Road corridor**: The whole of the road corridor from one frontage to the other including footpaths. Legally roads include beaches and places to which the public have access whether as of right or not.

**Roadway**: The part of the road used or reasonably usable by vehicular traffic in general.

**School speed zone**: Specially signed temporary speed limits covering the school zone for the time before and after school.

**School zone**: Area in the vicinity of a school where crossing assistance, safety measures and parking provision should be considered.

**Secondary collector roads**: These roads link local areas of population and economic sites. They may be the only route available to some places within this local area. Secondary collector roads support the active transport modes and may provide for significant numbers of pedestrians and cyclists (urban peak) or be part of identified cycling or walking network.

**Segregated shared-use path**: A route shared by pedestrians and cyclists where both groups use separate, designated areas of the path.

**Sensory-impaired pedestrian**: A pedestrian whose ability to walk is hampered by the partial or full loss of a sense, mainly sight or hearing. It may include those who are colour blind.

**Severance**: Separation of people from facilities and services they wish to use within their community due to obstacles to access such as busy roads.

**Shared zone**: A residential street that has been designed to slow traffic and signed to give priority to pedestrians. The shared zone sign means that traffic is required to give way to pedestrians but pedestrians must not unreasonably impede traffic.

**Shoulder**: The part of the road corridor outside the traffic lanes.

**Sight distance**: The distance, measured along the roadway, between a pedestrian about to enter the roadway and an approaching driver, or between two drivers, or between a driver and an object on the roadway.

**Street furniture**: Equipment within the footpath such as signal poles, lighting columns, signs, parking meters, seats, landscaping etc.

**Street furniture zone**: The part of the footpath between the through route and kerb zone primarily used for street furniture.

**Tactile paving**: A specially profiled footpath surface that can be felt underfoot. It is provided to warn or direct vision impaired people.

**Through route**: The central part of the footpath designed as the place where pedestrians have a continuous and accessible path of travel.

**Traffic calming**: Changes to the road environment to reduce driver speeds.

**Traffic reduction**: Changes to the road environment to reduce the number of vehicles travelling through an area.

**Transit Lane**: As defined in the Traffic Control Devices Rule and the Road User Rule. Generally a "transit lane" is a traffic lane set aside for the use of buses, cycles, motorcycles, taxis and vehicles carrying a specified minimum number of occupants. In certain circumstances (such as on motorways), cycles may be prohibited from using transit lanes.

**Trip destination**: The place a journey ends.

**Trip origin**: The place a journey starts.

**Unsegregated shared-use path**: A path shared by pedestrians and cyclists where both groups share the same space.

**Upstream**: The direction along a roadway from which the vehicle flow under consideration has come.

**Urban form**: The overall design and structure of settlements.

**Vision impaired pedestrian**: A pedestrian whose vision is reduced and cannot be adequately corrected by spectacles or contact lenses, and who may use tactile, visually contrasting and audible cues when walking.

**Vulnerable pedestrian**: Pedestrians at greater risk than others of being involved in a crash, or more susceptible to serious injury. It includes older people, impaired people and children.

**Walkability**: The extent to which the built environment is walking friendly.

**Walking**: The act of self-propelling along a route, whether on foot or on small wheels, or with aids.

**Woonerf**: Original Dutch name for a shared zone.

**Young pedestrian**: A pedestrian whose physical and cognitive development means their abilities have not reached those of normal adults.

**Zebra crossing**: A pedestrian crossing point with longitudinal markings, where traffic is required to give way to pedestrians on the crossing. Legally they are called pedestrian crossings.
Introduction

The purpose of this report is to provide public health unit staff, planners and decision makers with an overview of transport planning principles and a summary of the key infrastructure initiatives (and their application, including retrofitting) that help to provide a safe, healthy and efficient active and public transport network. Guidelines for public and active transport infrastructure design tend to focus mostly on safety issues and less often on the range of wider health issues (and potentially, health gains) (Schepersa et al., 2015). This report takes a public health view of bicycle, pedestrian and transit infrastructure provision, including not just road safety, but also the wider population health impacts stemming from physical activity and improved neighbourhood liveability.

Increasingly, there is shift towards providing public health input ‘up-stream’ in the drafting of policy and plans, to ensure that health is considered early in the process (i.e. before submission stage). Further, the consideration of cost/benefit ratios in transport infrastructure proposals is now commonly expected and/or required by legislation, and within this framework, health benefits (direct and indirect) are important inputs. Statutes such as the Resource Management Act 1991 and the Land Transport Amendment Act 1992 will require transport options to be fully evaluated under an effects-orientated framework, and to be consistent with the sustainable management resources (Longley, McChesney, Saunders, & Jollands, 1992).

This review has a focus on the safety-related design features of individual streets (notwithstanding that these occur within complex systems), rather than the wider issues of network design. Network design tends to focus more on catering for movement and in many cases the decision making processes for (pedestrian/cyclist) safety and (motor vehicle) movement will differ. There are many factors that can be considered in transport planning including economics, aesthetics, environmental sustainability, fuel efficiency, quality, service and satisfaction, capacity, travel time, social aspects, impacts of urban form, and health.

The examples and evidence presented in this report are principally viewed through a ‘public health lens’ and, inevitably, most of these transport-related variables act as direct or indirect determinants of health. The transport planning/outcome variable ‘level of Service’ (LOS) receives the most focus in this report because LOS refers to the perceived quality of the transport experience, which includes safety (and perceptions of safety). Overall, LOS is strongly related to the likelihood that a person will use particular mode of commuting (a higher mode-specific LOS value generally makes it more likely that people will use that particular transport mode). Active and public transport LOS is heavily influenced by the quality of infrastructure interventions. For example, fully separated cycle paths consistently provide higher LOS than painted cycle lanes, because (among other things) they are experienced as safe by cyclists (and cyclists or potential cyclists value safety greatly) (NCHRP, 2008). LOS can be viewed as a proxy measure\(^1\) for a number of relevant public health outcomes, these include (but are not limited to): reducing injury, the promotion of physical activity, improved wellbeing, and enhanced environmental sustainability (Kelly et al., 2014; Lefèvre, 2009;)

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\(^1\) Proxy measurement is the method of determining certain outcomes using calculable quantities or values when you do not have the ability to measure the exact value.
Newman & Kenworthy, 1999; Schepersa et al., 2015). Therefore, ‘safety’ need not be the only or necessarily most important outcome of interest (from a public health perspective) as safety is generally adequately captured by LOS. This report is necessarily limited in scope and includes only physical infrastructure interventions, not for example, policy or rules or education or media or social marketing campaigns. This review considers four specific types of roads under the NZTA’s ‘One Network Road Classification’ scheme (ONRC) (NZTA, 2013), specifically: arterial roads, primary collector and secondary collector roads, and access roads (not national or regional or roads).

This report is based on the review and synthesis of existing international and national transport planning guidelines and other published reports and analyses but it generally does not report on individual experimental trials of single infrastructure components, except for the purpose of example. However, this report does include a small selection of research studies because these key studies directly address questions of effectiveness and safety and the merit of some specific infrastructure interventions in specific road contexts (e.g. roundabout treatments). Findings from the included research studies also provide guidance on the level of infrastructure provision that is necessary to make a meaningful difference. This report provides information on costs to the extent that this information is reported by study/report authors (note: specific searching and reviewing of economic studies/publications has not been undertaken and a cost/benefit analysis has not been attempted, but basic cost comparison data has been presented when available).

Consideration has been given to any factors that might be especially relevant to the New Zealand context2; and local examples have been used where relevant/possible. This report also includes comment on any identified issues of equity.

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2 i.e. contextual factors (variables) that influence the effectiveness of a particular intervention, project, or application of a particular type of infrastructure or engineered solution.
Background

Over the past few decades, transport policy has focussed on providing road based infrastructure that is faster, wider and more efficient. These policies facilitate driving faster but they also tend to neglect the human impact of crashes, the often degraded conditions for walking and cycling and neighbourhood liveability. Despite these negative consequences, road traffic policy still tends to be predominantly car-centric by design (at least in developed countries). However, there are growing concerns across sectors about health, climate change, and other issues of sustainability. The historic emphasis on a supply oriented expansion of the transport infrastructure is, arguably, no longer appropriate when faced with budgetary and escalating environmental impacts (Longley et al., 1992). In addition, the ‘ideal’ of efficient road-based travel is increasingly under threat from traffic congestion.

Even among those proponents of intensely car-centric transport networks, there appears to be a slow realisation that business-as-usual (BAU) transport policy and practice is increasingly incompatible with a range of transport and non-transport goals (e.g. security of resource, cost efficiency, climate change and other environmental impacts, and the need to align with external regulatory agreements and emission standards). The main motivators for community advocacy tend to be around environmental issues and benefits to the local community whereas local government initiatives tend to be driven by regulatory motives as well as the triple bottom line of financial benefits, environmental benefits and social benefits (Ford, Doering, & Stephenson, 2014). It can be argued that supply oriented expansion of the transport infrastructure is no longer defensible when considering the wider context (i.e. sustainability).

In terms of the threat of climate change, urban transport energy consumption is where the most challenging problems need solving (particularly for low-density cities) and the types of policies adopted in the immediate future will have a crucial impact on long term energy consumption (Lefèvre, 2009). Low density metropolitan areas exhibit an almost total predominance of automobile use and total transport-related energy consumption tends to be high, whereas high density metropolitan areas tend to have an inherently more balanced distribution of car/active/public transport mode share (with public transport from 40% to 60% of travel) (Newman & Kenworthy, 1999). The spatial structure of a city (urban form), in particular the relative location of homes, employment and amenities, has a direct impact on the number and length of trips (Bertaud & Malpezzi, 2003).

Car transport is the dominant mode of commuting in greater Christchurch, with a slight increase between 2006 and 2013 – from 82.3 percent to 84.0 percent (Statistics New Zealand). The predominance of automobile use is consistent with low density metropolitan areas generally (Ministry of Transport, 2015a) as well as comparatively low use of public transport (i.e. bus, 3.7% mode share). Despite Christchurch’s reliance on the car, analysis has shown that most residential areas in the city of Christchurch do not inherently limit the adaptive options available to residents to adopt alternative travel modes (should they choose to³) (Rendall, 2012). However, in the case of the

³ Awareness and the availability of alternative travel modes does not necessarily ensure their adoption.
outlying areas, lifestyle properties, and the now growing satellite towns: the average trip distances do limit the ability of residents to adapt to future energy constraints and these areas consistently require large amounts of transport energy consumption⁴.

Post-earthquakes, Christchurch City’s spatial structure rapidly evolved into a polycentric pattern⁵ (Christchurch City Council, 2014a). Due to the extensive damage caused to multi-level commercial buildings, and sustained risk aversion, the CBD lost its primacy, and ‘activity clusters generating journeys’ are now distributed throughout the built-up urban area. The rapid transition to a polycentric pattern (combined with extensive damage to the horizontal infrastructure) caused significant disruption to all road users (Christchurch City Council, 2014a). On a city-wide scale, each new secondary activity centre has tended to generate travel from the whole urban area. Points of origin and destinations have become highly scattered for these trips and more random (because the location of businesses and dwellings has tended to be unplanned and independent). The altered distribution of activity clusters throughout the built-up urban area has also created significant disruption to public transport forcing a Metro Bus Services review and public consultation process in 2014 and subsequent network design changes⁶. Bus use in Christchurch city has been in decline for a number of years: between 2006 and 2013 patronage fell from 5.1 percent to 3.7 percent of people who went to work on census day, and overall bus use is reportedly still in decline post-network review⁷.

Some transport analysts consider that public transport is fundamentally incompatible with low density predominantly polycentric urban structures (Bertaud & Malpezzi, 2003; Lefèvre, 2009) and consequently, public transport systems are often subsidised because of low fare-recovery ratios⁸. According to Bertaud (2003), investment in public transport infrastructure is only economically justifiable if housing and employment density is sufficient within the catchment area of the stops. Some researchers and urban planners estimate the ‘density pertinence threshold’ for public transport to be approximately 3000 inhabitants/km² (Bertaud & Malpezzi, 2003). Christchurch has an average population density of 260/km². By comparison, this is approximately twenty times less dense than the city of London (5,432/km²). Bertaud’s analysis helps to define some of the interactions between urban form and transport systems. In terms of minimising transport energy use and greenhouse gas emissions, Bertaud and Malpezzi (2003) propose that cities need to remain

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⁴ With respect to the spatial distribution of trips, Zahavi and Talavitie (1980) observed a budget and time constant in urban mobility across a sample of World cities: the average time spent daily in transport is constant and equal to approximately one hour⁴ and an increase in the average speed of a transport system leads to lengthening travel distance, with, as a result, urban sprawl and reduced density and the associated negative effects (e.g. greenhouse gas emissions and the demise of active transport).

⁵ The polycentric city, the “urban village” type city with communities emerging around employment clusters (as compared to a monocentric city with a “Central Business District”)


⁸ However, economic viability is not the only driver for providing public transport.

⁹ The number of people who could potentially use public transport/ km² required for a bus service to be economically viable without subsidisation.
compatible with public transport, and stay dense and only moderately polycentric (or tend towards this pattern if possible).

In summary, the adoption of faster modes of transport fundamentally changes the spatial organisation of a city. The increase in average speed of a city’s transport system calls for more space. The result is diffuse urban sprawl and reduced density\(^\text{10}\), both giving rise to increased levels of transport energy expenditure (Lefèvre, 2009) and reduced compatibility with public and active transport modes. Dominant transport modes interact with (some say are the determinants of) urban structures (Newman & Kenworthy, 1999).

In greater Christchurch, car transport is the dominant mode of commuting. Journeys tend to cover long distances and are scattered and public transport is marginalised and tends to be used mainly by people who cannot drive or cannot afford to (Ministry of Transport, 2015c). A positive feature of Christchurch is its largely flat terrain which is conducive to cycling, and Christchurch has traditionally had a higher proportion of people cycling to work compared to National averages, especially in the central city. On census day in 2013, 7.0 percent of people living in Christchurch city cycled to work – up from 6.5 percent in 2006. Nationally, approximately 1-2% of people cycle to work, and cycling is generally in decline\(^\text{11}\), particularly among school children (Ministry of Transport, 2015a)\(^\text{12}\).

The demand for travel is a derived demand — the need to move is largely generated by individual exchanges within the city and the dispersion of areas of activity throughout the city (Lefèvre, 2009). Therefore, if environmental and sustainability objectives are to be met and cities are to be inherently more ‘liveable’, then highly structured city planning is required along with a transport system that includes public transport, cycling and walking infrastructure that affords high levels of service to users. Most agree that the greatest single barrier to increasing levels of active transport is safety. Lefèvre (2009) cautions that if urban design is not appropriate (i.e. there is no separation from street traffic, or adequate footpaths) then cycling and walking are dangerous and tend to disappear over time\(^\text{13}\).

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\(^{10}\) To some degree, Mass Rapid Transit (bus or rail based) can limit ‘diffuse’ sprawl as Mass Transit tends to concentrate urban development in accessibility corridors (only if the provision of transport systems is linked with appropriate land use policies, in a coordinated way).

\(^{11}\)By comparison, top ranking cities of the World have bicycle mode shares exceeding 15% with top ranking Copenhagen, Denmark increasing bicycle mode share from 36% to 45% between 2012 and 2014. http://copenhagenize.eu/index/01_copenhagen.html

\(^{12}\) While adult cycling in Christchurch appears to be trending positively over recent years, children are cycling less.

\(^{13}\) Despite the fact that the provision of cycling and walking infrastructure represents only a modest investment compared to ‘car-friendly’ infrastructure.
Methods

This review is based on a structured (but non-exhaustive) search of bibliographic databases including PubMed and of New Zealand and International government and statutory body websites (e.g. Transport Agencies), other transport-related agency websites and other English-language peer-reviewed research articles and design guidelines published from 2000 onwards. In addition, limited searches were conducted of a limited number of transport journals (e.g. The Journal of Transport and Health; International Journal of Behavioural Nutrition and Physical Activity; Accident Analysis and Prevention). Grey literature and unpublished material such as conference abstracts were not included in the search strategy. Figure 1 shows the main publications used in the preparation of this report.

The review style is a ‘technical brief’ that seeks to define, describe and illustrate cycling and pedestrian facilities appropriate for use in New Zealand. The review provides background, and guidance on infrastructure interventions and their application (including retrofitting), rather than a detailed research-trial based analysis of effectiveness for each and every type of infrastructure element.

This report lists, categorises, describes and outlines the relative merit and preferred active transport infrastructure options for different road classifications—drawing on evidence/examples from a range of existing international and New Zealand design guidelines (rather than creating new knowledge). The report uses the NZTA’s ‘One Network Road Classification’ scheme (ONRC) and the associated ‘Link and Place’ design philosophy (NZ Transport Agency, 2013) as the review framework (and uses or converts all information to standard New Zealand based terminology as necessary). Of the six ONRC functional categories the review focus on arterial, primary collector and secondary collector roads, and access roads (excludes national and regional roads).

The report does not include an economic analysis, however, minimal discussion of potential costs and benefits is provided to the extent that this information was available in the published papers/guidelines.

The research question addressed by this review is:

“What best-practice infrastructure interventions have been shown to increase pedestrian and cyclist safety (and perceptions of safety) across a range of contexts (i.e. different street ‘role’ or functional criteria) on arterial, primary collector, secondary collector and access roads and what best-practice transit infrastructure (bus) might be necessarily incorporated (coexist) in these street contexts, and to what effect (interactions)??

See Appendix A for a detailed description of the review methodology.
Figure 1: The main reference manuals and guidelines used in the preparation of this report

CCC (2013). Christchurch City Cycle Design Guidelines

Austroads (2013). Guide Information for Pedestrian Facilities


Austroads (2014). Cycling Aspects of Austroads Guides


NZTA (2009). Pedestrian planning and design guide

NZTA (2013). ONRC network road classification: Applying the One Network Road Classification, guidelines

The reader is also encouraged to refer to the original publications for more specific information and guidance, if more detail is required.


Austroads (2005). Bus-Bike Interaction within the road network
Findings

This guide uses text, tables, diagrams and photos throughout, and other key resources and references can be found in boxes, side-bars and the numerous footnotes. In addition a number of checklists and appraisal tools are included (each one indicated by a yellow highlighted arrow). Not all of these check-lists are validated appraisal tools, nevertheless, they are all extracts from published research and other design guidelines, and they may serve as useful prompts when considering transport infrastructure proposals/submissions. Finally, a 3-level summary checklist is provided at the end of this guide. The summary checklist covers network coherence, general planning principles and safety (Appendix E).

The benefits of active transport

This review does not seek to provide a detailed analysis of the benefits of active and public transport (and/or physical activity specifically as a component of active transport)—these have already been well described and are now widely accepted (for example, see Booth, Chakravarthy, Gordon, & Spangenberg, 2002 and Genter, Donovan, Petrenas, & Badland, 2008 for detailed analysis and discussion). However, for the purpose of summary, the following Table 1 presents the major economic, societal, environmental, and public health themes reported in the literature. Of these, facilitating population engagement in active transport (rather than driving to destinations) represents a major opportunity to support people in achieving recommended levels of physical activity and improved health status14 (Morris, 1994; Sahlqvist, Song, & Ogilvie, 2012). The potential advantages of increasing road safety and potentially levels of public and active transport usage are broad (Schepersa et al., 2015; Taylor, Kingham, & Koorey, 2009).

Table 1: Major economic, societal, environmental, and public health benefits of active and public transport

<table>
<thead>
<tr>
<th>Public health (being sufficiently physically active)</th>
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<tbody>
<tr>
<td>- Improves quality of life and life expectancy among adults (even if physical activity is adopted later in life),</td>
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<tr>
<td>- halves the risk of heart disease and stroke,</td>
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<td>- reduces the risk of some cancers (e.g. breast and colon cancer),</td>
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<td>- reduces the risk and improves the management of the most common form of diabetes,</td>
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<tr>
<td>- assists with the prevention of falls in the elderly by maintaining bone mineral density,</td>
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<td>- reduces the symptoms of depression and anxiety, lowers levels of stress,</td>
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<tr>
<td>- increases self-esteem,</td>
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<tr>
<td>- helps maintain a healthy weight, and</td>
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<td>- reduces air pollution and major respiratory illness.</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Societal</th>
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<tbody>
<tr>
<td>- Providing car spaces for parking uses up valuable land in and around cities.</td>
</tr>
<tr>
<td>- Walking, cycling and public transport can also help make a community more liveable, making it easier for people to connect with one another while travelling, working, shopping and socialising.</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Environmental</th>
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<tr>
<td>- Reduced air and noise pollution, and</td>
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<tr>
<td>- reduced greenhouse gas emissions.</td>
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<tr>
<th>Economic</th>
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<tbody>
<tr>
<td>- Financial benefits at the individual, community and national level including reductions in the cost of fuel, building roads, providing parking spaces, land use and opportunity costs,</td>
</tr>
<tr>
<td>- improved productivity i.e. the productive capacity of human resources measured in terms of both the quantity and quality of their output.</td>
</tr>
</tbody>
</table>

From: (Australian Department of Health, 2014; Booth et al., 2002; Kelly et al., 2014; Schepersa et al., 2015) and (Genter, Donovan, Petrenas, & Badland, 2008).

14 Insufficient exercise is a risk factor for chronic disease. New physical activity guidelines were introduced in Australia in 2013, increasing the minimum levels of physical activity needed to maintain health. Adults are recommended now to accumulate 150 to 300 minutes of moderate-intensity physical activity or 75 to 150 minutes of vigorous-intensity physical activity each week (Australian Department of Health, 2014).
Even when putting aside all arguments based on health, environmental and societal concerns, the problems caused by traffic congestion (e.g. economics, loss of productivity) still remain largely unsolvable without a transport strategy that makes walking, cycling, and the use of public transport more common (Schepersa et al., 2015). Health and fitness, congestion/liveability, and pollution/climate change appear to be the major drivers for the growing interest in cycling in Australia and New Zealand, as in other parts of the world (Bonham & Johnson, 2015).

Cycling, as a form of active travel, is increasingly being considered by all levels of government across Australia and New Zealand as well as by health promotion organisations. In New Zealand, New Plymouth, Hastings and Christchurch are examples of cities in which investment in urban environment transport-infrastructure is improving walking and cycling safety and providing for wider transport choices. Christchurch is perhaps a special case where “The council has a unique opportunity following the Canterbury earthquakes to make Christchurch a cycle city by developing a safe and connected cycle network” (Christchurch City Council, 2013, p.5). Improving the safety and accessibility for cycling was a strong theme for earthquake recovery to emerge from the ‘Share an Idea’ discussion in 2011 (Christchurch City Council, 2012). Based on international evidence, it is now well accepted that the two most important categories of interventions to improve active transport safety are separation and traffic calming. Box 1 provides a brief summary of the key elements required for safe, convenient and practical cycling based on an analysis of cities in the Netherlands, Denmark and Germany (Appendix A provides a more detailed list, from Pucher (2001)).

**Economics and health**

The New Zealand Land Authority commissioned a study to value economically the health benefits of cycling and walking modes (Genter, Donovan, Petrenas, & Badland, 2008). Elements of several methodologies were integrated and applied by the New Zealand researchers to estimate a value per km that could be easily incorporated into the existing economic evaluation methods. Mortality, morbidity and health-sector costs were all included in the total annual benefits that could be realised by an inactive person upon becoming physically active. These benefits were weighted and distributed across the average physical activity profile of the population to produce scenarios of an annual benefit per person. Genter et al. (2008) calculated that for cycling, this meant a per kilometre benefit of between $(NZ) 1.77 and $(NZ) 2.51, and for walking, a per kilometre benefit of between $(NZ) 3.53 and $(NZ) 5.01.

\[
\begin{align*}
&1.77 - 2.51 \text{ benefit/km} \\
&3.53 - 5.01 \text{ benefit/km}
\end{align*}
\]

Estimated benefit (SNZ) for cycling and walking, per kilometre, including mortality, morbidity and health-sector costs, from Genter et al. (2008).
The human cost of active transport
While the positive impacts of cycling on health, liveability and the environment are generally not disputed, there can be significant human costs for cyclists in particular (walking and public transport are both relatively safe modes of transport, see Figure 4). In New Zealand for example, an average of nine cyclists have been killed each year for the past ten years (Ministry of Transport, 2015e) and it is widely accepted that safety (real and perceived) is the single most influential factor in active transport participation. The top-five ranking countries for bicycle mode share (Germany, Sweden, Finland, Denmark and The Netherlands) have all invested heavily in active transport infrastructure and have achieved exceptional safety statistics, and mode shares of at least ten times that typically seen in Australia and New Zealand, the US and the UK. Dutch cities for example have undertaken substantial improvements to cycling infrastructure (and have restricted car use) and the result has been an 81% fall in the cyclist fatality rate from 1978 to 2006 (and a 36% increase in km cycled per inhabitant), and total child road deaths reduced from 400 in 1971 to 14 in 2010 (Cavenett, 2011; Netherlands Ministry of Transport, 2007). Cycling is over five times as safe in the Netherlands as in the USA and more than three times as safe as in the UK (Pucher & Buehler, 2008). While increasing the number of cyclists is related to improved safety statistics (the ‘safety in numbers’ effect), it is generally accepted that infrastructure ‘leads’ safety, and in countries like New Zealand, simply encouraging more people to cycle, without significantly improving infrastructure (and promoting pro-cycling culture) would likely have a negative safety impact. It is essential to provide safe, connected networks as international experience shows that the density of safety infrastructure, mode share and cyclist injury and fatality rates are closely interrelated (Pucher, 2001; Pucher, Dill, & Handy, 2010).

Figure 2 below shows average distances cycled per person against the number of cyclists killed per billion kilometres of travel. New Zealand’s performance is closest to the United Kingdom and France. The graph clearly shows a positive relationship between increasing cycle travel and increasing safety. This relationship does not prove causation in the statistical sense, but longitudinal studies in several countries suggest that increased safety is a key to promoting more cycling.
There is also evidence that more cycling facilitates safer cycling (given a fixed and adequate level of existing infrastructure). The phenomenon of ‘safety in numbers’ has been consistently found to hold over time and across cities and countries. Fatality rates fall for any given country or city as cycling levels rise (Jacobsen, 2003). Suggested mechanisms include increased driver awareness, an increase in the number of drivers who are also cyclists, and improved attitudes and a reduction in aggressive behaviour by drivers.\(^\text{15}\)

The use of cycle helmets is a factor that warrants special mention in discussions of active transport safety — although not infrastructure per se, cycle helmet laws do interact with some aspects of infrastructure delivery, and health outcomes (see Box 2). Evidence and expert opinion firmly indicates that the high level of cycling safety in Northern Europe is not due to widespread use of safety helmets. In the Netherlands for example, the safest cycling of any country, less than 1% of adult cyclists wear helmets, and even among children, only 3-5% wear helmets (Dutch Bicycling Federation, 2006). As well as direct discouragement (less convenient, less comfortable, and less fashionable), helmet laws may also contribute to the failure of public bike schemes that might otherwise boost mode share and the overall popularity of cycling (Fishman, Washington, & Haworth, 2012).

\(^{15}\) See also can.org.nz
Attempts to foster active transport futures are gaining momentum around the world (Bonham & Johnson, 2015). The implementation of cycling-friendly policies and cycling infrastructure in global (and aspiring global) cities sends a powerful message about the changing future of urban mobility. Cycling, as a form of active travel, is increasingly being considered by all levels of government across Australia and New Zealand as well as by health promotion organisations. In New Zealand, New Plymouth, Hastings and Christchurch are examples of cities in which investment in urban environment transport-infrastructure is improving walking and cycling safety and providing for wider transport choices. Post-earthquake Christchurch is perhaps a special case, as noted above. Improving the safety and accessibility for cycling was a strong theme for earthquake recovery to emerge from the ‘Share an Idea’ discussion in 2011 (Christchurch City Council, 2012). Based on international evidence, it is now well accepted that the two most important categories of interventions to improve active transport safety are separation and traffic calming. Box 3 (p.25) provides a brief summary of the key elements required for safe, convenient and practical cycling based on an analysis of cities in the Netherlands, Denmark and Germany (Appendix A provides a more detailed list, from Pucher (2001).

Box 2: Cycle helmets and safety

In an effort to reduce cycling head injuries, Australia introduced mandatory helmet legislation in 1991-92 (the first country in the World to do so) and New Zealand followed suit in 1994. This legislation has been consistently contested since its introduction (Clarke, 2012), and the rest of the world has not embraced this policy. The main objections about mandatory helmet use policies are that the efficacy of bicycle helmets in protecting cyclists has been exaggerated (R. Elvik, 2011); the legislation has had an extremely negative effect on cycling participation (Land Transport New Zealand, 2006; Sandblom, 2012); and the evidence for any meaningful reductions in rates of brain or head injuries is weak and it does not acknowledge the long-term downward trends that are/were already evident (Dennis, Ramsay, Turgeon, & Zarychanski, 2013).

- Currently only Australia and New Zealand still require and enforce universal use of helmets by cyclists. Other jurisdictions never adopted such legislation, or partial rules may apply for children, and some jurisdictions repealed their helmet laws altogether.
- Dutch cycling experts assert that helmets discourage cycling by making it less convenient, less comfortable, and less fashionable (and at best they provide a 15% reduction of the risk of injury to the head, the face or the neck if a bicycle helmet is worn (Elvik, 2011).
- There is some evidence that some people (children in particular) have been “oversold” on the safety benefits of their helmet and have been less cautious in their riding style as a result (Koorey, 2013).
- A number of international trials have shown that helmets are a major obstacle to bike share schemes because people are reluctant to use a supplied helmet because of hygiene concerns and carrying around a helmet defeats the purpose of a bike share (in addition to the generally discouraging effect described above).
The safety profile of road transport in New Zealand

Issues around active transport safety in New Zealand warrant finer analysis as certain trends and patterns provide insight as to where and how infrastructure might be improved. Absolute numbers of road crash deaths and injuries do not necessarily describe risk for different users as they do not take into account the amount of travel (time/distance). However, the amount of travel can be combined with crash statistics to compare the risk of death and injury for different age groups and by different modes of travel.

**Figure 3** shows the percentage of total travel time spent driving, as a car passenger, walking and cycling\(^\text{16}\), on public transport or by other means. ‘Other’ includes aircraft and boat travel and mobility scooters, as well as other modes like horse-riding (skateboarders and children in push chairs are included with walkers).

![Figure 3: Overall mode share, share of total travel time, New Zealand 2011-2014](image)

**Data source:** The New Zealand Household Travel Survey reported in (Ministry of Transport, 2015b).

**Risk of injury**

Of these different travel modes, cycling is the second most risky mode of travel in New Zealand\(^\text{17}\) (Figure 4). In the four years July 2010 – June 2014, on average 9 cyclists each year died and 757 cyclists each year were recorded as injured in motor vehicle crashes (31 deaths/injuries per million hours travelled). Following cycling, drivers and passengers of light four-wheeled vehicles\(^\text{18}\) incur death/injury rates of eight and five deaths/injuries per million hours travelled (respectively). In 2015, 73% (232/319) of all road deaths in New Zealand were either motor vehicle drivers of passengers (12 months ending January 2016, NZTA)\(^\text{19}\). The two safest modes of road transport are walking and being a bus passenger. In the four years July 2010 – June 2014, an average of 34 pedestrians died and 892

\(^{16}\)Cycling participation rates in Australia and New Zealand are amongst the lowest among Western countries (New Zealand, Australia, the US and the UK all approximately 1% versus Denmark 18% and The Netherlands 27%) (Pucher & Buehler, 2008).

\(^{17}\)The highest risk mode of travel is motorcycling (196 deaths/injuries per million hours travelled).

\(^{18}\)A four-wheeled vehicle that has a gross vehicle mass not exceeding 3.5 tonnes.

\(^{19}\)https://www.nzta.govt.nz/resources/road-deaths/toll.html
pedestrians were injured in motor vehicle crashes each year (4.6 deaths/injuries per million hours travelled). Being a bus passenger is the safest mode of road travel in New Zealand (0.7 deaths/injuries per million hours travelled) (Ministry of Transport, 2015e). Death rates also vary by age, for any given severity of accident. Children and those over 70 years old are more physically fragile and therefore more likely to die or be injured in a crash.

Figure 4: Road transport injuries or deaths per million hours spent travelling by mode, New Zealand 2011-2014

![Figure 4](image)

Figure 4 shows the number of people who died or were injured in motor vehicle crashes per million hours spent travelling. Motorcycling is the riskiest travel mode by time (196 deaths/injuries per million hours travelled), followed by cycling (31 deaths/injuries per million hours travelled). Drivers of light 4-wheeled vehicles have a similar risk (8 deaths/injuries per million hours travelled) to passengers in light 4-wheeled vehicles (5), and the two safest modes of those shown are walking (4.6) and being a bus passenger (0.7). The death and injury data are from police reported crashes involving motor vehicles from the Crash Analysis System (CAS). This analysis does not include pedestrian and cyclist falls or incidents not involving a motor vehicle (reported in Ministry of Transport, 2015e).

Given this risk profile, discussions about active transport safety are often centred on cycling because of its relatively higher risk when compared to walking. Cyclists have a number of risk factors that do not affect car drivers. The main risk factors are decreased stability and a much lower level of protection than that provided by a car. In addition, a cyclist is less visible to other road users than a car or truck. These factors combined place cyclists at a high level of risk per unit time travelled. Bus travel is largely ignored as travel by bus is comparatively risk free in New Zealand. There is a large difference between cycling and walking in total mode share (≈2% for cycling and 13% for walking) and pedestrians already spend most of their commute in physically separated environments (footpaths). Therefore, the greatest relative gains in safety (and potentially in mode share) will be derived from improving cycling infrastructure (ideally, by a modal shift away from driving). It should be noted that bus and cycling infrastructure may interact (possibly negatively) on any given roadway and special consideration should be given to any interactions that threaten cyclist safety and/or the level of service provided to cyclists (e.g. where cyclists have to share bus lanes). The focus on bus infrastructure is usually (traditionally) centred on efficiency and level of service, as it is already a safe way to travel (for the bus passengers).
Where cycling accidents occur

Figure 5 shows the percentage of fatal and serious\textsuperscript{20} crashes (on-road cycle crashes involving a motor vehicle) occurring by urban junction type and non-junction sites (i.e. mid-block), New Zealand, 2003-2012. Approximately three-quarters of all urban fatal and serious cycling crashes occur at a junction, with “T” junctions accounting for the highest number of cyclist collisions of any junction type. Conversely, on rural roads, approximately 70% of crashes occur not-at-a-junction (the typical crash involves a cyclist being struck from behind on a straight road).

**Figure 5: Crash site, fatal and serious crashes, for cyclists, 2003-2012, urban New Zealand**

\begin{figure}  
\centering  
\includegraphics[width=\textwidth]{figure5.png}  
\caption{Crash site, fatal and serious crashes, for cyclists, 2003-2012, urban New Zealand}  
\end{figure}

*Source:* Data from the Crash Analysis System (CAS) as reported in Leggat & the Cycling Safety Panel, (2014) and the Ministry of Transport (2015)\textsuperscript{21}

Figure 5 shows the proportions of serious and fatal crashes by crash site, overall. The proportions are strongly related to the total number of each type of intersection within the road network. For example, “T” and “X” junctions are by far the most common on the network (and account for the highest absolute number of cyclist collisions overall), and roundabouts are relatively uncommon compared to all other types of intersections. However, while roundabouts generally have a good safety record for motor vehicle users, they have a poor safety record with respect to cyclist crashes (i.e. the highest rates of crashes of any intersection type), particularly large roundabouts with multiple lanes.

Who is involved?

Pedestrians

In absolute terms, in 2014, 43 pedestrians died, 221 pedestrians were seriously injured, and 614 pedestrians suffered minor injuries in police-reported crashes on New Zealand roads. Eight were “pedestrian–unsupervised child” (under 18yrs) crashes (Ministry of Health, 2015). The majority of reported pedestrian crashes (over 60%) occur mid-block, rather than at intersections. Eight out of

\textsuperscript{20} Involving fractures, concussions, internal injuries, crushings, severe cuts and lacerations, severe general shock necessitating medical treatment and any other injury involving removal to and detention in hospital.

ten occur at un-controlled sites, with around one in ten occurring on signalised crossings, and a further one in ten at or near a ‘zebra’ crossing.

The highest risk is for those aged 5–9 years (deaths/injuries, adjusted per million km walked) and over 80 years old (approximately 50 deaths or injuries/year, not shown in Figure 6), however, as noted above, these are physically fragile age groups who are more likely to be injured or die when in a crash (Ministry of Transport, 2015d).

Figure 6: Pedestrian deaths or injuries in motor vehicle crashes (unadjusted for distance walked, annual average) by age and gender, 2010-2014

Cyclists
In absolute terms, for 2014, 10 cyclists died, 158 were seriously injured and 573 suffered minor injuries in police-reported crashes on New Zealand roads. This is about 6 percent of the total number of casualties from police reported crashes in 2014.

Figure 7: Average number of cyclist deaths or injuries in motor vehicle crashes pre per million hours cycled

Figure 6 and Figure 7 show a similar pattern: deaths and injuries per distance cycled or walked are concentrated around the young. Generally, pedestrians and cyclists aged 5–17 years (particularly the former) have a higher risk of death or injury than adults per distance travelled. This is in part related to the time spent in the road environment; children cycle and walk more slowly than adults so take longer to cover the same distance (Ministry of Transport, 2015b).
**Travel to school**

Although travel to school makes up only about four percent of trip legs in New Zealand, the health implications for children and the timing of school travel within the morning peak make it a topic of interest. Children’s independent mobility appears to be an important independent determinant of weekday physical activity for both boys and girls (Page, Cooper, Griew, Davis, & Hillsdon, 2009). Cycling to school has dropped from 12% of journeys to primary school in the 1989/1998 New Zealand Household Travel survey to 2% of journeys in 2008 (Ministry of Transport, 2015c). The proportion of primary school-aged students being driven to school has increased sharply over the same period (from 45% to 71%)\(^\text{22}\), and the proportion walking to school dropped from 42% to 25% (Figure 8).

![Figure 8: Primary school children- travel from home to school, New Zealand 1989-2008](image)

**Data source:** (Ministry of Transport, 2015c)

Similar trends are evident for ages 13–17, although walking has remained relatively stable at 26% and the overall transport mode profile is more mixed\(^\text{23}\). In summary, the majority of school children in New Zealand drive or are driven to school, approximately one quarter walk and very few cycle.

Children aged 0-14 years are at most risk of hospitalisation due to a traffic crash injury. An analysis of pedestrian-motor vehicle crashes resulting in deaths or injuries (per year by hour of day and age) showed that that most deaths and injuries occur in children (under 18yrs, almost double that of 18+) between 3pm and 4pm (followed by 8am and 9am). This coincides with the times children walk the most, most likely going to and from school (Ministry of Transport, 2015d). The analysis reported a rate of 33.5 child pedestrian hospitalisations per 100,000 head of population. Children living in the Auckland region are most at risk. Their rate of hospitalisation was found to be 49.5 per 100,000 (NZTA, 2015)\(^\text{24}\).

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\(^\text{22}\) Mostly single leg trips as passengers in a private car, but including combined trip legs including car or bus (e.g. when children get dropped to or walk to a bus stop then continue on by bus).

\(^\text{23}\) Since 2003–07, increases in children being driven to school and decreases in active transport to school have slowed.

\(^\text{24}\) They are followed by older adults aged 65 plus and young people aged 15-24 years, both with rates of 26.5 per 100,000. Adults aged 25-64 years are least at risk (11 per 100,000) http://www.nzta.govt.nz/resources/nz-pedestrian-profile/6/
Although walking is relatively safe at the population level (safer than driving or being a passenger in a car, see Figure 4), there appears to be an opportunity for focused interventions to improve the safety of to-and-from school journeys. The NZTA has noted that there appears to be a lack of progress in reducing pedestrian accident hospitalisation rates, despite a trend of slightly declining walking activity (NZTA, 2015).

**Fundamental approaches to improving active transport safety**

The bicycle is a transport mode that is often in competition with other transport modes. The daily cycle commute should be able to co-exist with car and public transport\(^\text{25}\).

Taking a system approach to road traffic injury prevention, road traffic injury is the result of energy transfer. This fundamental idea can be applied across the full scope of traffic planning, policy and implementation. Early work by Haddon (1972) resulted in a greater appreciation of the role that energy transfer plays in road traffic injuries. Haddon developed a matrix (The Haddon Matrix)\(^\text{26}\) that describes the human, vehicle, and environmental factors within the three phases before, during, and after the crash that might be explanatory and contribute to injury prevention strategies (e.g. prevention of the marshalling of energy, mitigating energy transfer). A guiding principle of injury control that emerged from Haddon’s work was that effective injury control relied on a combination of intervention strategies (ranging from ‘big picture’ to specific infrastructure interventions, e.g. Box 3).

Haddon proposed that a logical starting point for injury prevention is the prevention of the marshalling of energy in the first place. Much research has focused on the influence collision speed has on the probability of serious injury and death for pedestrians as pedestrians (and cyclists) are particularly vulnerable to serious injury. In a vehicle-pedestrian collision, the probability of survival for the pedestrian decreases dramatically at impact speeds above about 30 km/h (clearly shown in Figure 9).

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\(^{25}\) International experience clearly shows that cyclists cannot be moved from shopping streets/main traffic arteries to back streets: arguably, planners should focus on providing good cycling facilities on shopping streets even when this is at the expense of motor traffic (Anderson et al. 2012).

\(^{26}\) Haddon’s Matrix has been applied to Transport for London’s Road Safety Action Plan for London 2020.
Later studies by Elvik and others (e.g. Elvik, 2013), showed that fatal crashes decline more substantially with the same amount of mean speed reduction than all injury crashes. In other words, severity of crashes decreases with reduced mean speed (and fatalities in particular drop off sharply below 30 km/h). The role of speed in crash likelihood has also been confirmed through numerous studies. For example, Nilsson (2004) and then Elvik (2013) demonstrated that lower mean traffic speeds in response to speed limit reduction result in reduced likelihood of casualty crashes. Kloeden et al. (2001, 2002) also demonstrated that the likelihood of driver involvement in a casualty crash increased with his or her speed. The angle of impact has also been shown to be an important factor in crash severity (Wramborg, 2005). This speed-angle concept has been adopted in Australia and New Zealand to analyse the effect of impact speeds on severity of selected crash types. Wramborg (2005) proposed three impact speed–fatality probability relationships, extending the relationship shown in Figure 9 to include pedestrian-cyclist collisions, side impacts and head on collisions.

The Safe System approach to road safety management recognises that humans make errors, that crashes will continue to occur and that humans have a limited tolerance to impact forces. In the pedestrian context, this means ensuring that facilities provided for pedestrians do not expose them to the likelihood of serious injury or death, that vehicles and pedestrians are separated physically or temporally, or that the speed environment is controlled to keep potential impact speeds and angles within survivable limits. The range of facilities provided in the road and traffic system to accommodate active transport users includes footpaths along urban streets, crossing facilities at midblock and intersection locations (signalised or unsignalised), off-street pathways (exclusive or shared), stairs, ramps, waiting or queuing areas, specific pedestrian/cycling streets or malls and shared zones.

**Basic principles in active transport infrastructure design**

As mentioned previously, improving cycling infrastructure represents the best opportunity to improve active transport mode share. The development of active transport infrastructure can be based on different principles and safety objectives will often (but not always) be included. Conventionally, the aim of road safety work is to prevent accidents, and not necessarily to encourage more people to walk or cycle (it is generally accepted that pedestrians and cyclists’ subjective sense of security or safety is the key factor that actually encourages active transport, cycling in particular). Creating an environment that conveys a better sense of security may be an explicit objective of some infrastructure plans and strategies, however this is generally less clearly formulated (and measurable) than other design objectives. It is possible to increase cycle traffic and
improve road safety at the same time, however many factors influence accident rates. In some European cities (e.g. Copenhagen and other ‘cycle-friendly’ cities), cycling has been embedded as the dominant factor in the traffic environment, essentially defining the traffic flow (i.e. the dominant philosophy is no longer car-centric). The concept of ‘critical mass’ is relevant here. The mechanism is that when high numbers of cyclists are present, drivers watch out for cyclists and possible conflicts. When the critical mass of bicycle traffic has been reached, the accident trend is favourable (i.e. more cyclists mean fewer accidents). This is in sharp contrast to the situation in many cities which start out with very few cyclists: in this case (without a focused investment in safety infrastructure) more cyclists will typically result in more accidents – and more negative headlines (Andersen et al., 2012).

Heavily trafficked, high speed roads with few cyclists should have cycle paths on safety grounds alone. In areas currently without bicycle traffic, the sole basis for prioritisation should be cycling potential. In the case of new construction, an increase in modal share of cyclists can be anticipated if cycling facilities are favourable. This broader public health focus on mode share goes beyond traditional exposure-related injury prevention and requires greater consideration of the factors that convey safety to potential and current active transport users.

**Physical separation**

The first major category of cycling infrastructure is physical separation via lanes and paths as mid-block treatments. There is now widespread (but not unanimous) support for separated cycle paths\(^{27}\) from existing cyclists, potential cyclists, and policy makers and a degree of official acceptance of the fact that no other potential solutions to date have been successful in achieving the high levels of cycling (and cycling safety) common in many parts of Europe (Pucher & Buehler, 2008; Pucher et al., 2010). Separated cycle facilities are seen by many as the cure-all for low cycling mode share and safety, based on their use in European countries, however, they are not without some limitations and challenges. Well-designed separated cycle paths are expensive to plan and construct, may be compromised by available width and/or may require parking removal, require suitable intersection treatments, and may impact negatively on other road users (Box 4). Also, the European examples may not necessarily translate entirely to Australasian contexts due to differing traffic regulations with respect to right-of-way, differences in driver experience and culture, differences in the levels of traffic calming of adjacent neighbourhoods, and differences in the levels of education and enforcement (none of which can necessarily be modified by the installation of stand-alone infrastructure interventions) (Pucher et al., 2010).

However, there is now good evidence for the installation of extensive systems of separate fully integrated paths (including off-street short-cuts, such as mid-block connections). Such separated paths might be achieved by the use of raised cycle-lane separators and vertical delineator posts, kerbs, low islands, longitudinal barriers, planter boxes, and other separation infrastructure, subject to available width. Note that separated cycle paths alone are seldom considered sufficient and complete solutions and broader supporting treatments have been recommended including wider

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\(^{27}\) The discussion is largely centred on safety for cyclists because pedestrians are already provided with separated paths (footpaths).
kerbside lanes and shoulders, drain grate replacement, pothole patching, clear lane markings, and bike-activated traffic signals (Pucher, 2001).

Bicycle lanes and bicycle paths have been found to reduce collision frequency and injury rates compared with roads with mixed traffic (Schepersa et al., 2015). A comprehensive review found reported injury rate reductions for cycle lanes of between 9% and 50% (R. Elvik, 2009). Counterintuitively, smaller effects were reported for cycle paths but three important factors need to be considered. Firstly, it appears that the quality or effectiveness of intersection treatments greatly influences risk exposure (and studies vary in the degree to which they control for increases in absolute numbers of cyclists or ‘exposure’). For example, the review study by Elvik (2009) found a negative safety benefit of 7% while a later high quality study by Lusk et al. (2011) demonstrated a 38% reduction of injury and fatal bike-vs-motor vehicle crashes with the use of separated cycle paths (Lusk et al., 2011). In a later review of the evidence, Thomas and DeRobertis (2013) summarised the most effective intersections and estimated the probable gains in safety attributable to each (Table 2).

Table 2: Apparently effective intersection treatments for use with separated cycle paths

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Gains in safety</th>
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<tbody>
<tr>
<td><strong>Parallel treatments (convert path to lane)</strong></td>
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</tr>
<tr>
<td>– Bringing the cycle track closer to the parallel auto traffic at the intersection approach to increase the visibility of cyclists to motorists (e.g. convert cycle path to cycle lane 20–30 m in advance of intersection†).</td>
<td>31% - 51%</td>
</tr>
<tr>
<td>– Bring together but maintain physical separation, also with the use of advance stop line for motorists 3–5 m behind waiting cyclists.</td>
<td></td>
</tr>
<tr>
<td><strong>Raised cycle crossings</strong></td>
<td></td>
</tr>
<tr>
<td>– Raising cycle crossings to the level of the cycle path, essentially providing a speed hump, to lower vehicle turning speeds and reduce injuries to cyclists.</td>
<td>33%</td>
</tr>
<tr>
<td><strong>High-visibility painted surfaces</strong></td>
<td></td>
</tr>
<tr>
<td>– Coloured cycle crossings (green) through intersections (less effective if overused).</td>
<td>10-19%</td>
</tr>
<tr>
<td>– Bicycle stencil in advance of intersection on cross-street approach.</td>
<td></td>
</tr>
<tr>
<td><strong>Signals</strong></td>
<td></td>
</tr>
<tr>
<td>– Providing dedicated cyclist signals to separate the cyclist through-movement from turning vehicles.</td>
<td>High‡</td>
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*No attempt was made to quantify the effects of combining a number of intervention elements.† This solution is reportedly unpopular among cyclists because it makes them feel less safe, however the evidence suggests objectively measured safety is increased.‡ This has generally not been quantified formally, probably because prioritised signals are already known to provide a temporal separation between motorists and cyclists.

Source: summarised from Thomas & DeRobertis (2013)

Secondly, bicycle paths (versus cycle lanes) will attract cyclists to roads with the highest (pre-existing) risk profiles, because this is where cycle paths are typically applied. Therefore safety data from cycle paths and lanes are difficult to compare directly. Any increases in absolute accident/injury risk therefore needs to be considered within the context of the particular local network (Schepersa et al., 2015). Many studies on the safety of urban bicycle lanes and paths to date have not controlled for shifts in the numbers of cyclists across networks after bicycle paths were built (change in route choice and absolute numbers). It is therefore not valid to directly compare crash/injury data from cyclists on distributor roads with cyclists on residential roads—such comparisons are likely to result in rather conservative expectations of the road safety impact of lanes and paths.
Thirdly, several studies suggest that the risks faced by pedestrians and cyclists are highly non-linear. As the number of pedestrians or cyclists increases, the risk faced by each pedestrian or cyclist goes down. The model estimates presented by Elvik et al. (2009) suggest that, if circumstances are favourable, transferring a substantial proportion of trips made by motor vehicles to walking or cycling may lead to fewer accidents even though walking or cycling generally involves a 5–10 times higher risk of injury per kilometre travelled than driving a car.

**Traffic calming**

The second major category of cycling/pedestrian safety infrastructure is traffic calming. Road-based traffic calming (infrastructure) is a strategy developed to reduce the negative impacts of high-density motorised traffic and to better enable active transport. Traffic calming devices/schemes (see Table 6) are generally introduced into a road to encourage drivers to travel at an appropriate speed for their surroundings, and to discourage unnecessary through-traffic. The introduction of a traffic calming device can provide a higher level of safety for all road users, while also making streets more pleasant, particularly for pedestrians and cyclists. A traffic calming device may be introduced (retrofitted) in isolation, to solve a particular problem at a specific location, or as part of an area-wide scheme or route treatment. Traffic calming measures are commonly applied to create more favourable conditions for mixed traffic (i.e. reduce the speed, volume and type of traffic), thereby allowing for cycling without any other specific cycling provisions.

Reducing injuries (and the perceived risk of injuries) due to traffic collisions is a particular focus of road-based traffic calming and is of particular relevance to both transport planning and public health. Road-based traffic calming may be achieved by speed limits alone (e.g. 30 km/hr) or via any combination of the following physical infrastructure deterrents (for cars and trucks) including: bicycle streets (narrow roads where bikes have absolute priority over cars), ‘Home Zones’ (with 7 km/hr speed limit, where cars must yield to pedestrians and cyclists using the road), road markings and signs, kerb line alterations (known as ‘build outs’), pedestrian refuges, roundabouts and mini-roundabouts, road humps, tables and platforms, surface treatments, raised intersections, chicanes, rumble strips (judder bars), speed cushions and other measures including road closures. Various combinations of road-based traffic calming strategies are now used across most major cities in New Zealand (to varying degrees) and around the world (Lieswyn et al., 2012; LTSA, 2004).

In new urban developments, traffic calming should be considered as an integral part of the design (along with land-use planning). The lay-out of the road network can be used to combine low traffic areas and cycling bypasses into a coherent network. A system of cycle bypasses and short-cuts is an effective way to give the advantage to sustainable traffic modes. A preliminary cycling design audit for any important new development is a way to detect any issues in advance. Traffic management and land-use planning, has a crucial, long-lasting structural impact on traffic and modal split (Andersen et al., 2012; Lieswyn et al., 2012). Table 6 (page 48) lists and describes a number of common traffic calming devices.

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28 Apart from the benefits afforded to pedestrians and cyclists, traffic calming measures are generally popular with inhabitants of residential areas as they are perceived as increasing the quality of the local environment in terms of safety, noise reduction and reclaiming public space.

29 After road trauma, the second major issue leading to a rethink of road based infrastructure is urban congestion, which has both economic and liveability implications.

30 Although putting up 30 km/h speed limit signs alone is generally not enough to ensure low speeds.
The ‘Link’ and ‘Place’ functions of roads

Background

The new One Network Road Classification (ONRC)31 (NZTA, 2013) involves categorising roads based on the functions they perform as part of an integrated New Zealand network. The classification system aims to help local government and the Transport Agency to plan, invest in, maintain and operate the road network in a more strategic, consistent and affordable way throughout the country. The ONRC project has three elements. The first is classifying roads into categories based on their function in the national network (completed in December 2013). The second element is the customer levels of service (CLOS), which defines what the fit-for-purpose outcomes are for each category in terms of mobility, safety, accessibility and amenity. The third element is the development of the performance measures and targets, which effectively determine how the categories and customer levels of service translate into specific maintenance, operational and investment decisions (the first of the ONRC performance measures were released in December 2015)32. The ONRC considers the needs of all road users, be they motorists, cyclists or pedestrians. It aims to give road users consistency and certainty about what standard and services to expect on the national road network, including the most appropriate safety features (see also the ONRC infographic, Appendix C)33.

Road classification

Road classification involves categorising roads based on their main function(s). Criteria and thresholds have been identified based on the relative importance of roads in the context of the national network: that is, their ‘Link’ function and ‘Place’ functions are particularly important at the local level and in urban environments. Ten functional criteria (such as daily traffic, percent heavy vehicles, bus, active transport modes) have been used and they are a mix of proxies for measuring roads’ economic growth and productivity contribution, their social contribution and their ‘link’ and ‘place’ functions (listed and described in Appendix C, see also Box 5).

Key Resource 1: The ONRC matrix source materials

The detailed ONRC matrix, classifications, functional criteria, and thresholds can be downloaded at nzta.govt.nz/assets/Road-Efficiency-Group-2/docs/functional-classification.pdf. Or they can be found in the publication “Applying the One Network Road Classification guidelines”, NZTA, (2013).


32 The first measures were: crash counts, intersection crashes, and average roughness and chipseal resurfacing quantity.

33 See https://www.nzta.govt.nz/assets/Road-Efficiency-Group-2/docs/onrc-right-road-right-value-right-time-map.pdf
The ten variables that determine road classification are weighted and applied to a given road (or road segment) to determine its functional categorisation as either a: national, regional, arterial, primary collector, secondary collector or access road (these six functional categories are described in detail in the Glossary).

Conventionally, the urban road network has been classified simply in terms of the importance of its general traffic movement function (the ‘Link’ function). The twin concepts of ‘Link’ and ‘Place’ provide the basis for developing a more comprehensive two-dimensional street classification, in which every kind of urban street is represented by both link and place dimensions. This more comprehensive classification system provides stakeholders with a more structured approach to evaluating infrastructure proposals. Each relevant street activity will have a ‘minimum’ and ‘desirable’ level of space provision.

While at desirable levels of provision each activity would normally have its own dedicated space, at minimum levels of provision it may sometimes be possible (or necessary) to share space, either by mixing activities (e.g., bus and cycle lane), or by allocating different time slots (e.g., a peak period bus lane and off-peak loading bays). By summing up the space requirements for the relevant Link and Place activities, it is possible to identify total Link and total Place requirements, within the street cross section, at minimum and desirable levels of provision. At one extreme, the full width of the road corridor could be allocated to Link activities, (e.g., an urban motorway, Figure 15, page 51); at the other extreme it could all be allocated to Place activities (e.g., an urban square). Usually, however, a proportion of space is allocated to both functions. In some cases, there may be insufficient space to accommodate even the minimum levels of provision; and the best solution is likely to be to downgrade either the Link or Place function of that street segment. The Place status of each part of the street network may not have been agreed and local authorities may need to engage stakeholders in a consultation process to define agreed values for the Place status of different street segments.

Customer Level of Service (CLOS)
CLOS describes the ‘fit for purpose’ customer experience each category of road (described above) should provide to road users, over time, if the road is to fulfil its function within the national network.

The six variables selected are:

- Travel time reliability: the consistency of travel times that road users can expect
- Resilience: the availability and restoration of each road when there is a weather or emergency event
- Optimal speeds (safety and efficiency): indicates the optimal speed for each road
- Safety: how road users experience the safety of the road
- Travel quality and aesthetics: the level of travel comfort experienced by the road user and aspects of the road environment
- Accessibility: the ease with which people are able to reach key destinations and the transport networks available to them - includes land use access and network connectivity
Using the Link-Place framework as an appraisal tool

The Link-Place approach to planning and designing urban streets recognises that all roads have both ‘Link’ and ‘Place’ functions. Both functions have their own sets of design requirements, and often compete for scarce space and capacity (Jones & Boujenko, 2011). As can be seen from the above lists, the One Network Road Classification (ONRC) system comprises a system for the categorisation of roads (six categories) and a system for defining the expected/desirable level of service criteria and thresholds (six variables). While the scope of the ONRC is broad (including maintenance, operational and investment judgments) the ONRC does specifically include safety and the active transport modes (including transit). Using the ONRC and the link-place concepts, any CLOS variable (for example safety) can be selected as a particular focus, and the degree to which an infrastructure proposal meets certain safety criteria might be appraised using the four-stage approach suggested below34.

Practical application: a four-stage approach to appraising infrastructure proposals35

i. Identify the relevant Link and Place performance indicators that reflect the potential range of street users and street problems (these might include indicators of transport performance, safety, economic vitality and environmental quality).

ii. Identify the (potential) ‘degree of problem’ (if any) for each indicator (i.e., if considering safety, how far away is the proposal from delivering a minimum acceptable level of safety?). This can be assessed on an agreed rating scale, such as from 0 (no problem) to 10 (severe problem).

iii. Consider which function (Link or Place) has the higher priority (consider the relative weightings based on the Link/Place categories for each road segment – as expressed by stakeholders).

iv. Recommend/implement changes to the proposal if required: recognising that the link requirements have to be balanced against a wide range of other place-related needs that may have equal legitimacy. In practice, the optimal design solutions may vary along a corridor, even if the link status remains the same throughout, due to the varying importance and nature of place user needs, and differences in the available street width, from one road segment to the next.

Adapted from: Jones & Boujenko (2011)

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34 This approach is suited to ‘single-mode’ appraisals (e.g. assessing a proposal from the perspective of cyclists, but not all road users). For more complex appraisals see ‘Multi-Modal Level of Service’ below.

35 This more balanced approach to street planning and design can be applied in the case of lightly-trafficked residential roads as well as busier streets (for example these principles have now been incorporated in the Manual for Streets 2 (CIHT, 2010) and illustrated in several case studies in Australia and the UK (Jones & Boujenko, 2011) (CIHT 2010).
Multi-Modal Level of Service

The Link-Place concept described above offers planners and consultants (submitters) a structured approach to evaluating infrastructure projects — particularly with regard to retrofitting existing arterial, primary collector and secondary roads (Box 6). However, for larger scale network planning and analysis in complex settings, a more detailed analytical framework might be required to fully assess the performance of a road corridor. Such a ‘multi-modal level of service’ (MMLOS) framework has been developed in the US by the National Cooperative Highway Research Program (NCHRP). The urban street level of service(a) for a given mode is defined as “the average degree of satisfaction with the urban street that would be reported by a large group of travellers using that mode of travel if they had travelled the full length of the study section of the street” (NCHRP, 2008, p.92). Using the NCHRP’s methods in part or in full may be useful for planers and submitters, within a design/consultation process. Using the New Zealand One Network Road Classification (ONRC) system (including customer levels of service) and the NCHRP’s multi-modal levels of service variables (Table 3) might provide additional perspective to infrastructure proposals/appraisal.

The MMLOS methodology has its origins in the era of rapid expansion in the use and availability of the private motor car. The primary concern for auto drivers was congestion, and it was commonly held that only the rapid expansion of motorway networks would keep congestion in check. Over time, the MMLOS concept has increasingly been applied to public transportation (such factors as wait time, frequency of service, time it takes to pay fares, quality of the ride, accessibility of depots) and more recently to the active transport modes (e.g. walking and cycling). Considerable

Notes

[36] LOS is a ‘selfish’ measure. It considers only the perspective of the traveller. It does not take into account how many people will actually use the facility or how expensive it is to the agency and the general public to provide the facility. It does not consider environmental concerns or collision rates.
research efforts have now been made to evaluate urban transportation services (of roadways) from a multimodal perspective (i.e. considering auto drivers’, transit passengers’, cyclists’, and pedestrians’ perceptions of level of service together for a section of road infrastructure) (Dowling, 2009; NCHRP, 2008).

Considering LOS beyond that of auto drivers has been driven by the need to improve non-automobile modes and achieve community goals such as reducing congestion and curbing urban sprawl. More than 30 factors have been identified as influential in determining the level of service perceived by different road users. These factors include delay, traffic signal efficiency, arrows/lanes for turning vehicles, clear/legible signs and road markings, geometric design of intersection, leading right-turn phasing scheme, visual clutter/distractions, size of intersection, pavement quality, queue length, traffic mix, location, scenery/aesthetics, and presence of pedestrians and cyclists (and associated active transport infrastructure) (Pecheux, Pietrucha, & Jovanis, 2000). By using a MMLOS approach, agencies can model and balance the level of service needs of all uses in their street designs. The NCHRP’s modelling system relies on 37 variables to predict the perceived degree of satisfaction experienced by travellers on the urban street (Table 3).

Table 3: The 37 NCHRP modelling system variables

<table>
<thead>
<tr>
<th>Mode</th>
<th>Auto (car)</th>
<th>Bus</th>
<th>Cycle</th>
<th>Pedestrian</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS inputs or variables</td>
<td>Stops or delays</td>
<td>Pedestrian LOS*</td>
<td>Bike-Pedestrian conflicts*</td>
<td>Pedestrian density</td>
</tr>
<tr>
<td></td>
<td>Right turn lanes</td>
<td>Bus headway</td>
<td>Driveway conflicts/Km</td>
<td>Pedestrian-Bike conflicts†</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bus speed</td>
<td>Vehicles per hour</td>
<td>Width of shoulder</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bus schedule adherence</td>
<td>Vehicle through lanes</td>
<td>Width of outside lane</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passenger load</td>
<td>Auto speed</td>
<td>On-street parking occupancy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bus stop amenities</td>
<td>Percent heavy vehicles</td>
<td>Presence of trees</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Pavement condition</td>
<td>Footpath width</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Width of outside lane</td>
<td>Distance to travel lane</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>On-street parking occupancy</td>
<td>Vehicles per hour</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Vehicle through lanes</td>
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<td></td>
<td></td>
<td>Average vehicle speed</td>
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<td></td>
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<td></td>
<td></td>
<td>Left turns on red</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Side street speed</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>Side street vehicles/hour</td>
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<td></td>
<td></td>
<td>Side street lanes</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Crossing delay</td>
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<td></td>
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<td></td>
<td></td>
<td>Left-Turn channelisation</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>Block length</td>
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<td></td>
<td>Signal cycle length</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Signal green time</td>
</tr>
</tbody>
</table>

*Because transitioning to transit modes almost always involves a pedestrian segment.

†Pedestrian/bike conflicts come into play only for paths outside of roadway but within right-of-way of street.

The NCHRP’s modelling system relies on 37 variables to predict the perceived degree of satisfaction experienced by travellers on the urban street. These variables consist of four basic types: facility design, facility control, transit service characteristics, and the volume of vehicle traffic on the facility.

37 The LOS multimodal method does not address perceived quality of service for commercial vehicle drivers (trucks, taxis, etc.), auto passengers, messenger and delivery services, recreational users, or rail transit users.

38 Environmental factors that fall outside of the right-of-way, such as buildings, parking lots, scenery, and landscaped areas are specifically excluded from the formal LOS methodology, because these factors are generally not specifically under the direct control of the agency operating the urban street. However, these factors can still be included in an overall assessment of a proposal, as they may have implications for predicting/influencing pedestrian and cyclist route choice.
**Bicycle LOS: a special case**
Cyclists are highly sensitive to rough surfaces, caused by repairs for example, and the state of cycle track surfaces impacts significantly on cycling LOS. Quality criteria may be based on subjective experience or objective measurement.

From a safety and health perspective, the repair of potholes, patches, subsidence, and cracking (including repainting worn lane markings) should be high priority to preserve the LOS of routes and cyclist safety and participation (even though from an operational/economic point of view, other road transport priorities might seem more important). Assessment methods may include regular inspection, as well as enquiries and complaints from citizens and interest groups (including app-based reporting supported with GPS data). Gully grates and manhole covers and other such fixtures located within the cyclist circulation area should be flush. Seemingly small details are important to cyclists, for example ramps should be finished with a ‘smooth invert’ (Figure 10) to minimise jolts or bumps (Austroads, 2009b) (although in Christchurch, this is seldom achieved in practice). Cyclists will often try to avoid cycling over manhole covers, grates and other non-flush infrastructure and may be tempted to make a dangerous swerve when these occur within the line of travel (Andersen et al., 2012).

![Figure 10: Example of kerb ramp with smooth invert](image)

**Note:** The quality of the transitions onto the ramp, or from the ramp onto the road can significantly influence cyclist behaviour, line, and route choice.

The provision of a gently graded and smooth invert at the gutter is a vital design feature for the safety and comfort of all path users, including cyclists (Andersen et al., 2012; Austroads, 2009b, 2014a). Kerb ramps on bicycle facilities require other features to ensure that they are safe and convenient for use by cyclists, including for example the width of the ramp should match the width of the path, where cyclists need to turn left from the road onto the ramp, or from the ramp onto the road, a satisfactory turning radius (or skew) should be provided, and in some cases flatter kerb ramps of 1:15 should be considered to provide more efficient and comfortable movement for cyclists between the road and the ramp (Austroads, 2009b).

**Smooth travel exposure: a 30yr deficit for Christchurch?**
It is well recognised that a smooth riding surface has significant LOS and safety (and route choice) benefits for cyclists. Reduced smooth travel exposure negatively impacts travel time, enjoyment and safety for cyclists and may significantly influence cycling mode share. The earthquake legacy presents the Christchurch City Council with a number of challenges, as the condition of the network and corresponding levels of service have been severely impacted (Figure 11). Further, freight volumes through and around Christchurch have risen sharply during the rebuild period (expected to
at least double by 2041) and this is resulting in increased wear and tear on the network and a corresponding strain on maintenance and renewal budgets (Christchurch City Council, 2014a, 2014b). It has been estimated that it will take approximately 30 years to return the assets to their pre-quake condition (Christchurch City Council, 2014b). This situation is likely to have a significant impact on cycling in Christchurch for some years. Although the CCC has set the priority level for a localised programme of smoothing works as “very high”, it remains unclear how and when this will translate into improved LOS for cyclists (commuter cyclists in particular). On the positive side, the network of 13 Major Cycle Routes planned or under construction in Christchurch via the Urban Cycleways Programme, 39 will provide mainly high/very high LOS including high smooth travel exposure along newly constructed sections of cycle path/lanes (Appendix D).

Figure 11: Damaged and patched surface within a cycle lane, Riccarton Road, post-earthquakes, Christchurch, 2016

Surface damage and uneven and highly cambered roads present serious hazards to cyclists and such road conditions are typical of many areas of the City.

Photo: David Brinson, 2016

39 The Urban Cycleways Programme is made up of shared investment from the Urban Cycleways Fund (Government), the National Land Transport Fund (NZ Transport Agency) and local councils. This enables key, high-value urban cycling projects to get underway around the country over the next three years, improving cycle safety and supporting more connected cycle networks.
As previously shown in Table 3, there are a range of factors that influence cyclists’ perceptions of LOS, and within that, their perceptions of safety (and these can directly and indirectly influence their behaviours). In addition, crash analysis studies have gone some way towards quantifying safety objectively and identifying the main risk factors. Motor vehicle speed, volume, and proximity (exposure/conflicts) are the main influences on safety with ‘percent heavy vehicles’, ‘driveway conflicts/Km’, ‘on-street parking occupancy’, and ‘pavement condition’ also being important to cyclists. When considering the type of bicycle facility to include on any road segment (such as bicycle lanes or shared use paths), the two most important guiding principles are separating cyclists from motor vehicles and providing a high level of priority for cyclists across driveways and through intersections (Austroads, 2014a).

**Figure 12** (below) is the most commonly used quick-guide chart for the selection of an appropriate type of bicycle facility. To provide local context, Table 4 has been added under the figure to show examples of Christchurch roads and their two-way daily 24hr traffic volumes (and these can be related back to the figure). Figure 12 illustrates the degree of separation required for cyclists as a function of the speed and volume of the general traffic flow. It should, however, be noted that local policy and implementation strategies may also influence selection of particular facilities (i.e. overall cohesiveness, consistency, purpose and the experience/skill/age of the target cyclist population should be considered when a proposed facility falls within a major cycle link project). This figure has been widely reproduced and can be found in many national design guidelines (e.g., Austroads, 2014a; RTA, 2003, 2005) although some argue (Andersen et al., 2012) that a number of the assumptions needed to draw the figure are not fully documented and that the figure is based on only a small number of relatively old studies (specifically, Centre for Research and Contract Standardization in Civil and Traffic Engineering (CROW), 1993; DELG, 1999; Ove Arup and Partners 1997; RTA, 2003). A further, potential defect of this figure is that the number of cyclists is not included and cross traffic volumes (for all types of traffic) and the distance between intersections are also absent (i.e. driveway and intersection conflicts/Km).

Notwithstanding these potential limitations, the figure does convey the key message that the separation of cyclists from motor vehicles is not always required on local and collector roads. When traffic volumes are less than 5000 vehicles per day and speeds less than 40 km/h, it is considered appropriate that adult cyclists may share the road with motor vehicles and younger cyclists may use the footpath where this is supported by appropriate road rules (although where space permits, it is still important to consider the provision of a separated bicycle facility such as a bicycle lane or a shared use path). However, above these thresholds, increasing levels of separation are generally recommended (this standard is likely to be difficult to achieve in retro-fit situations).
Further, a number of caveats and notes have been added to the chart in successive publications (e.g., Austroads, 2014a) and these should be considered and weighted alongside the basic thresholds shown on the chart —

1. Experienced road cyclists are unlikely to use off-road facilities with low design speeds, even on routes where the road carries high volume, high speed traffic. On-road bicycle lanes or suitable road shoulders may still be required in addition to off-road facilities.

2. In general, roads with higher traffic speed and traffic volumes are more difficult for cyclists to negotiate than roads with lower speeds and volumes. The threshold for comfort and safety for cyclists is a function of both traffic speed and volume, and varies by cyclist experience and trip purpose. Facilities based on this chart will have the broadest appeal.

3. When school cyclists are numerous or the route is primarily used for recreation, path treatments may be preferable to road treatments (also path widths need to be wide enough to accommodate school cyclists in particular, as school cyclists tend to be numerous and clustered).

4. Provision of a separated cycle path does not necessarily imply that an on-road solution would not also be useful, and vice versa.

5. Different kinds of cyclists have different needs. Family groups may prefer off-road cycle paths while racing or training cyclists, or commuters, tend to prefer cycle lanes or wide sealed shoulders.
Figure 12: Preferred separation of bicycles and motor vehicles according to traffic speed and volume


Table 4: Examples of Christchurch roads and their two-way daily 24hr traffic volumes

<table>
<thead>
<tr>
<th>Road</th>
<th>Section</th>
<th>Two-way volume (daily 24hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riccarton Road</td>
<td>Overall</td>
<td>24000</td>
</tr>
<tr>
<td>Papanui Road</td>
<td>Bealey Ave-Main North Road</td>
<td>19000</td>
</tr>
<tr>
<td>Colombo Street</td>
<td>Brougham St.-Cashmere Rd.</td>
<td>15070</td>
</tr>
<tr>
<td>Tuam Street</td>
<td>Overall</td>
<td>8800</td>
</tr>
<tr>
<td>Colombo Street</td>
<td>Tuam St.-Brougham St.</td>
<td>7300</td>
</tr>
<tr>
<td>Bridle Path Road</td>
<td>Ferry Road-Tunnel Road</td>
<td>4900</td>
</tr>
</tbody>
</table>

Source: Christchurch City Council, Christchurch road level classification 2012

Table 4 lists six prominent roads in Christchurch and their respective traffic flows (Christchurch road level classification list, 2012). Reference to Figure 12 illustrates that all of the top five roads in Table 4 exceed the 5000 vehicles per day/40kph thresholds shown in Figure 12 and the top three arguably meet the criteria for separated paths.

The influence of bicycle infrastructure on bicycle use

Several recent review studies have attempted to describe and quantify the impact of new bicycle infrastructure on bicycle use (Heinen, Panter, & Mackett, 2015; Pucher et al., 2010; Schepersa et al., 2015). However, answering this fundamental question is complex as most of the research to date has been correlational (measuring the extent to which two variables are related) with few before-and-after studies having been conducted. Correlational studies make it difficult to infer causality and assess the nature of the relationship, due to confounding factors such as shifts in route choice and shifts in surrounding land use (development). Notwithstanding these limitations, correlational studies generally do show a positive relationship between the availability of cycle paths and commuting by cycle. One notable study included over 40 US cities and the results demonstrated a positive dose-response relationship. The study showed each additional 1.6km of bicycle lane per square km area to be associated with an increase of approximately one percentage point bicycle modal share (i.e. 1.6%/km/km²) (Barnes, Thompson, & Krizek, 2006; Dill & Carr, 2003; Pucher et al., 2010).

Barnes et al. (2006) estimated the effect on modal choice in Minneapolis-St. Paul, US, of routes installed with on-street bicycle lanes and standalone bicycle paths (of about an equal length) using before and after census data within a one mile buffer each side of the routes. The analysis suggested an increase of bicycle modal share of 1%/km/km². An early before-after study of the Delft bicycle network in the 1980s is particularly important because it was conducted in Netherlands where bicycle modal share is much higher than in the US. The intervention included the construction of a number of new bicycle paths, lanes, and standalone tracks at a level of infrastructure density reaching 0.9 km/km². Bicycle modal share increased from 40% to 43% (with no decrease in walking time) (Wilmink & Hartman, 1987). It was found in Copenhagen (also an area with a high bicycle modal share) that average daily cycle traffic on streets newly equipped with bicycle paths increased by around 19%, while motorised traffic decreased by 10%. The latter suggests that at least part of the effect is due to modal shift.

Taken together, in particular comparing the outcomes of the studies by Dill and Carr (2003) and Barnes et al. (2006), it appears that an increase of bicycle modal share between 0.9% and 1.5% /km/km² is likely when installing new cycling infrastructure. Pucher et al. (2010) conclude that evaluation research is rare but is needed to more accurately determine the effect of bicycle paths on cycling mode share.

Commuter cyclists will go-out-of-their-way by ≈10% to avoid a busy unsignalised intersection (right turn) but enjoy a -11% distance equivalent when traveling on a separated bike path or boulevard. Based on GPS data from Broach et al. (2012), Portland USA.

*Routes must go where people want to go, be joined up, direct, and preferably faster.
**Route choice**

Studies consistently suggest that cyclists prefer ‘bicycle friendly’ infrastructure (Pucher et al., 2010). Cyclists balance total journey length and route directness and prefer low motor traffic volumes, separated bicycle paths, bicycle boulevards 41 and bicycle lanes, although distance and time remain the most important factors (Broach, Dill, & Gliebe, 2012).

Broach et al (2012) conducted an innovative ‘revealed preference GPS data study’ and modelled cyclists’ preferences for separated bike paths and bike boulevards. For commute trips42, travel on bike boulevards was found to be equivalent to decreasing distance by almost 11% (for non-commute trips, 17.9%). Travel on separated bike paths was found to be equivalent to reducing distance by 16% for commute trips and 26% for non-commute trips (Broach et al., 2012). Further, the data indicated that a commuter cyclist would be willing to travel an additional 9% to avoid a right turn at an unsignalised intersection (with through traffic volume of 10,000–20,000 vehicles per day), and a non-commuter 16% further.

In summary, Broach et al (2012) concluded that cyclists are willing to go considerably out of their way for separated paths, followed by bicycle boulevards. Painted bike lanes were only preferred when separation was not an option, though they were highly valued compared to high traffic streets without a painted lane. Avoiding high traffic was one of the two most important factors in route choice, along with minimising time (for commuting).

**Midblock facilities for cyclists and pedestrians**

Providing for cycling in the midblock sections of streets (and in parks and rail corridors) may be categorised as shown in Figure 13. The nine types of lanes and paths across the top row in the figure also have to be considered alongside intersection treatments, as some combinations can be problematic. The tenth type, ‘trails’ do not typically form an intersection with a road corridor. All of the nine terms describe typical sealed paths/lanes available for cycling (and shared-use in some cases) in urban environments in New Zealand. Within the road corridor (also known as the road reserve, or the area between property boundaries), lanes are always at carriageway level and paths are elevated above the carriageway level by a kerb, where kerbs are provided. Separated bicycle facilities (SBFs) refer to physical separation from motorised traffic. They can be one-way (on each side of the road) or two-way (on one side of the road). The second row of Figure 13 lists a further nine sub-categories of the four most widely used and important lane/path types, specifically: the painted cycle lane, protected cycle lane, the cycle path and the shared path. Generally, moving from left to right across the figure indicates increasing levels of separation and safety for cyclists. Common pedestrian facilities are listed.

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41 Bicycle boulevards are a type of bikeway composed of a low-speed street which has been optimised for bicycle traffic: including traffic calming measures to discourage cut-through motor-vehicle traffic but allow local motor-vehicle traffic and give priority to bicyclists as through-going traffic.

42 Commuting cyclists are likely under greater time pressure to reach their destination, particularly in the work direction.
Summary of cycling and shared use midblock facility types by provision category and selected pedestrian facilities

**Figure 13:** Summary of cycling (and shared use) midblock facility types by provision category

Compiled from: Austroads, 2009a, 2009b, 2014a; Lieswyn et al., 2012; NZTA, 2009a and other relevant guidelines
Below, Table 5 lists and describes a number of the most common mid-block facility types that aim to improve cycling and pedestrian LOS and safety. The advantages and disadvantages of selected infrastructure types are listed, and for cycling, the infrastructure elements are rated for suitability for novice cyclists including children and for experienced/commuter cyclists using a 5-star rating. The table is based on existing guides and design manuals, New Zealand legislation and the collective opinions of a range of cycling and pedestrian facility planners and commentators (the table does not comprise a full design guide, however further information is available in the cited literature). Then, Table 6 lists and describes a number of common traffic calming devices, as mid-block facilities, for cyclists and pedestrians. Traffic calming devices are primarily used to encourage drivers to travel at an appropriate speed for their surroundings, and to discourage unnecessary through-traffic. Following the tables, a series of figures, photographs and diagrams are provided to illustrate the different types of infrastructure (shown collectively by Figures 14-18).

### Table 5: Definitions of mid-block facility types for cyclists and pedestrians

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition of mid-block facility types for cyclists and pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle lane (Kerbside)</td>
<td><strong>Suitability for Child/Novice cyclist = ★ ★</strong>  <strong>Suitability for Experienced cyclist = ★ ★ ★ ★ ★★</strong>  Subcategories of cycle lanes include buffered cycle lanes and contra-flow cycle lanes. Cycle lanes may be adjacent to the kerb (“kerb-side”), adjacent to motor vehicle parking (“car-side”), or between general traffic lanes on the approach to intersections. The delineation is typically achieved by use of pavement markings, with cycle symbols and lane lines as a minimum and coloured surfacing optional. Cycle lanes next to parallel parking should be of the following minimum widths: speed limit or 85th percentile speed 50 km/h = minimum cycle lane width 1.8m and 70 km/h = minimum width 2.2 m (<a href="#">Austroads, 2014a</a>).  &gt; • Advantages: All road users are likely to recognise the cycle lane and expect to find cyclists there. It provides a degree of separation between motor traffic and cyclists. Reported injury rate reductions for cycle lanes of between 9% and 50%.  &gt; • Disadvantages: This facility restricts car parking. It may not provide enough protection for inexperienced cyclists.  &gt; • Summary: As long as car parking issues can be resolved, kerbside cycle lanes are the favoured facility for roads.</td>
</tr>
<tr>
<td>Cycle lane (Car-side)</td>
<td><strong>Suitability for Child/Novice cyclist = ★</strong>  <strong>Suitability for Experienced cyclist = ★ ★ ★ ★★★</strong>  Advantages: Eliminates the need for parking restrictions and improves the channelling of traffic, encouraging a more orderly and predictable traffic flow.  &gt; • Disadvantages: A significant carriageway width is required. Exposes cyclists to the collision risk with car doors.  &gt; • Summary: If the road is wide and parking restrictions are unlikely to be acceptable, a cycle lane next to parking is likely to be an appropriate choice. Kerbs protruding the width of the parking bay should be constructed at intervals to discourage vehicles travelling over unoccupied parking spaces.</td>
</tr>
<tr>
<td>Cycle lane (Contra-flow)</td>
<td><strong>Suitability for Child/Novice cyclist = ★</strong>  <strong>Suitability for Experienced cyclist = ★ ★ ★ ★★★</strong>  Advantages: Contra-flow lanes contribute to the network’s directness and coherence by allowing cyclists to avoid diversions along indirect or less safe routes.  &gt; • Disadvantages: Other road users, including pedestrians, may not expect cyclists to travel in the opposite direction to other traffic. Contra-flow lanes generally preclude parking on the cyclist’s side of the road.  &gt; • Summary: Contra-flow cycle lanes can be used in one-way streets where cyclists might otherwise be forced to divert along indirect or less safe routes. Intersection layouts must support this facility, particularly at start and end points and at side road intersections.</td>
</tr>
<tr>
<td>Enhanced cycle lane</td>
<td><strong>Suitability for Child/Novice cyclist = ★ ★</strong>  <strong>Suitability for Experienced cyclist = ★ ★ ★ ★★★</strong>  Cycle lanes may be enhanced by individual measures such as traffic islands and physical separation at bus stops and other special treatments at side roads, if separated bicycle facilities are not possible.</td>
</tr>
<tr>
<td>Buffered cycle lane</td>
<td>The buffer is usually created by hatched markings but may also be formed by textured surfaces such as flush pavers or flush printed asphalt. Kerb-side buffered cycle lanes are permissible, however consideration should be given to using the buffer space for stronger separation elements such as bollards, kerbs or flags whereupon the buffered cycle lane becomes a protected cycle lane.</td>
</tr>
</tbody>
</table>

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43) Motor traffic volume, speed and in some cases the age profile of cyclists using the route can and should influence the choice between a cycle lane, cycle path or mixed traffic solution. Principles for a high standard of intersection design are crucial and should have top priority.
A sealed shoulder might be used for parking or for emergency stops and may serve as space for cyclists if pathway intended for recreation, sport and tourism walking and cycling, however “track” is frequently used in New Zealand to formed paths to downhill and shared between cyclists, day walkers and trampers, and sometimes equestrians. Trails may range from rail trails or similar formed paths to downhill and cross country unformed paths suitable for mountain bikes. The term trail is used to describe a pathway intended for recreation, sport and tourism walking and cycling, however “track” is frequently used in New Zealand to mean a mountain bike facility.

**Protected cycle lane**

<table>
<thead>
<tr>
<th>Suitability for Child/Novice cyclist</th>
<th>Suitability for Experienced cyclist</th>
<th>SBF</th>
</tr>
</thead>
<tbody>
<tr>
<td>★★★★★</td>
<td>★★★★★</td>
<td>SBF</td>
</tr>
</tbody>
</table>

Also known as a “separated bicycle lane”, a protected cycle lane is not accessible to cars (except to cross for driveway access). The protection may be provided via raised kerbs, flags, bollards, landscape planters, or other vertical elements. Consideration should be given to the durability of vertical elements employed. One-way and two-way protected cycle lanes are possible (although two-way protected cycle lanes introduce additional complexities at intersections). Protected cycle lanes can offer a low-stress environment that can be attractive to many cyclists. In comparison to a shared path, a two-way protected cycle lane is further from the nearest property boundary and therefore offers better intervisibility between cyclists and motor vehicle drivers exiting a driveway (Figure 16 & Figure 17).

**Cycle path**

<table>
<thead>
<tr>
<th>Suitability for Child/Novice cyclist</th>
<th>Suitability for Experienced cyclist</th>
<th>SBF</th>
</tr>
</thead>
<tbody>
<tr>
<td>★★★★★</td>
<td>★★★★</td>
<td>SBF</td>
</tr>
</tbody>
</table>

An off-street path can be an exclusive cycle path, a shared use path or a separated path. (LTSA 2004) A cycle path may be within the road reserve, in a park, alongside a river, lake or railway line (NZTA 2008) although typically if not in a road corridor it will be termed a shared path. They may be marked and/or signposted for one-way or two-way cycling. Legally a cycle path may also be used by pedestrians and includes a cycle track formed under section 332 of the Local Government Act 1974.... even if not specifically designated as a shared path.

- **Advantages:** Separated paths may help to avoid the conflict between pedestrians and cyclists that is common on shared paths. Cyclists can ride without the delays possible on paths shared with walkers.
- **Disadvantages:** Under New Zealand traffic law, cyclists on paths are required to give way to other traffic when crossing side roads. This results in delay for cyclists. Separated paths are wider than other paths, so they cost more. Higher cyclist speeds are possible and separated paths require special intersection treatments to ensure that high speeds are controlled at intersections and that cyclists can merge safely. It is less convenient to turn right from a protected cycle lane next to a road. Cyclists have to cross the whole traffic stream in one manoeuvre, whereas from a cycle lane they can first merge across to the centre. However, a right turn from a separate path may be safer.

- **Summary:** Separated paths are appropriate if large numbers of cyclists will use them. There should be adequate separation (such as different path levels) between cyclists and pedestrians. Between intersections, cycle paths next to roads can provide attractive and safe facilities for a wide range of cyclists, provided there is adequate space and interference from other users is minimal.

**Danish cycle track**

<table>
<thead>
<tr>
<th>Suitability for Child/Novice cyclist</th>
<th>Suitability for Experienced cyclist</th>
<th>SBF</th>
</tr>
</thead>
<tbody>
<tr>
<td>★★★★</td>
<td>★★★★</td>
<td>SBF</td>
</tr>
</tbody>
</table>

A Danish cycle track is a sub-type of cycle path which is elevated above the carriageway, for the exclusive use of cyclists, separated from traffic, contained within a road corridor, and adjacent to the footpath (In New Zealand the term track may be confused with mountain bike trails. Therefore, adding the word Danish helps distinguish the term). Motor vehicle parking, where provided, is located between the track and the general traffic lanes on the carriageway. As with protected cycle lanes, locating the facility on the passenger side of parked cars reduces car-door opening conflict.

- **Advantages:** This facility is useful to cyclists as well as pedestrians, and therefore maximises the benefit of the path to the general community.
- **Disadvantages:** Conflict between cyclists and pedestrians is common where there is a significant volume of cyclists and pedestrians or a mix of recreational walkers and commuting cyclists. The LOS for cyclists can be poor where interference by other path users results in slower speeds.
- **Summary:** Shared paths are beneficial to a range of path users but need to be managed effectively. They are appropriate where both cyclists and pedestrians need a path, but their numbers are modest.

**Shared path**

<table>
<thead>
<tr>
<th>Suitability for Child/Novice cyclist</th>
<th>Suitability for Experienced cyclist</th>
<th>SBF</th>
</tr>
</thead>
<tbody>
<tr>
<td>★★★★★</td>
<td>★★★★★</td>
<td>SBF</td>
</tr>
</tbody>
</table>

Shared paths can be alongside roads or separate from them, such as in parks or alongside rail lines, rivers, coastlines or lakeshores. They typically feature a sealed surface. They should have good separation from boundaries (to provide improved visibility at driveways), vegetation or other forms of potential side friction (see Error! Reference source not found.).

- **Advantages:** This facility is useful to cyclists as well as pedestrians, and therefore maximises the benefit of the path to the general community.
- **Disadvantages:** Conflict between cyclists and pedestrians is common where there is a significant volume of cyclists and pedestrians or a mix of recreational walkers and commuting cyclists. The LOS for cyclists can be poor where interference by other path users results in slower speeds.
- **Summary:** Shared paths are beneficial to a range of path users but need to be managed effectively. They are appropriate where both cyclists and pedestrians need a path, but their numbers are modest.

**Cycle trail**

<table>
<thead>
<tr>
<th>Variable suitability depending on user expectations</th>
<th>SBF</th>
</tr>
</thead>
</table>

A trail is typically (but not necessarily) unsealed and located in a public reserve; recreational in focus; located in a rural area; and shared between cyclists, day walkers and trampers, and sometimes equestrians. Trails may range from rail-trails or similar formed paths to downhill and cross country unformed paths suitable for mountain bikes. The term trail is used to describe a pathway intended for recreation, sport and tourism walking and cycling, however “track” is frequently used in New Zealand to mean a mountain bike facility.

**Sealed shoulder**

<table>
<thead>
<tr>
<th>Suitability for Child/Novice cyclist</th>
<th>Suitability for Experienced cyclist</th>
<th>SBF</th>
</tr>
</thead>
<tbody>
<tr>
<td>★★</td>
<td>★★★★★</td>
<td>SBF</td>
</tr>
</tbody>
</table>

A sealed shoulder might be used for parking or for emergency stops and may serve as space for cyclists if sufficiently wide. This is typically (but not always) a rural treatment.

- **Advantages:** Widened shoulders benefit all road users.
- **Disadvantages:** Sealed shoulders usually narrow at bridges, at passing lanes, and at intersections with turn lanes. Generally, motorists travel at high speeds along roads with sealed shoulders, so cyclists are at significant risk in these situations. Sealed shoulders are sometimes low of surface quality, contrary to cyclists’ requirements.
- **Summary:** Sealed shoulders provide some benefits to cyclists.
Bus lane

Suitability for Child/Novice cyclist = ★
Suitability for Experienced cyclist = ★★★★

A lane reserved by a marking and/or sign for the use of buses. Whilst it is desirable that bicycles are accommodated in a separate bicycle lane, examples exist where bicycles have successfully shared in the use of bus lanes. Alternatively, it may be possible to provide a separate on-road bicycle lane or off-road bicycle path adjacent to the bus lane and/or at bus stops. The design of bus lanes must incorporate the needs of cyclists. Bus lanes are not perceived as quality cycling infrastructure by many cyclists (particularly by novice and non-confident cyclists).

- Advantages: Bus lanes may be more easily justified than either bus-only lanes or cycle lanes alone, as they benefit both buses and cyclists.
- Disadvantages: The LOS is limited, as buses obstruct cyclists by stopping regularly — and in narrow lanes cyclists can prevent buses passing. Lane widths where drivers are unsure whether there is sufficient room to pass, create the conflicts.
- Summary: Wide lanes should be used wherever possible so that buses can pass cyclists within the lane.

Slip lane/cycle bypass

A facility to avoid a traffic calming device, public transport stop, or intersection control. Bypasses may also be provided at the head of T-junction intersections or as a left turn slip lane (i.e. may be either a mid-block or intersection treatment).

Wide Kerbside Lanes

Suitability for Child/Novice cyclist = ★★
Suitability for Experienced cyclist = ★★★★

- Advantages: This facility requires less space than the combined width of a travel lane and a cycle lane.
- Disadvantages: Wide kerbside lanes do not highlight cyclists’ legitimate presence on the road.
- Summary: Wide kerbside lanes should be considered where no other facility is possible.

Notes: Suitability of cycle facility option for different cyclist categories is subjective only. One ★ = minimal benefit, ★★★ = moderate benefit, ★★★★ = most benefit

SBF = Separated bicycle facility

Source: adapted from (Lieswyn et al., 2012), (Austroads, 2014a), (NZTA, 2008), and (Andersen et al., 2012).
Table 6: Definitions of traffic calming devices as mid-block facilities for cyclists and pedestrians

**Horizontal narrowing**
Horizontally narrowing the road profile, including actively removing a lane from the street. It is important to create bypasses for cyclists. Pinch-points are places where the road momentarily narrows, to slow down motorised traffic. When badly designed, street narrowing measures may be uncomfortable or dangerous for cyclists. Cyclists should be able to bypass pinch points in a straight line. The cyclist should not be forced to negotiate the pinch-point together with traffic. Horizontal narrowing can have a significant effect on both speed and the number of vehicles using a street.

**Vertical speed reducers (general)**
The most cycle-friendly devices are those that do not take up the entire width of the road, such as speed cushions or bollards to block car access physically. In these cases, cycle bypasses can be provided (allows cyclists to continue on a direct route). Cycle bypasses should have the width of a cycle lane and be clearly marked with a bicycle symbol and appropriate signage.

**Block or restrict access/diverters**
Such traffic calming means include: median diverters to prevent right turns or through-movements into a residential area, converting an intersection into a cul-de-sac or dead end, closing of streets to create pedestrian zones. These treatments can, however, inconvenience local residents by requiring them to take a more indirect path to their home.

**Diagonal parking**
Diagonal parking may be installed as a simple way of narrowing the road while increasing parking capacity.

**Kerb extensions (buildouts)**
Widening the pavement and/or pavement buildouts at intersections or in the mid-block. May be used to reduce the width at pedestrian crossings (good increase in visibility of pedestrians to drivers and approaching vehicles to pedestrians).

**Chicanes**
Kerb extensions and/or traffic islands which create a horizontal deflection, used to narrow the width of the roadway in an offset pattern, to create an ‘s’ path that forces traffic to slow.

**Central refuges**
Protected place of refuge permitting pedestrians to cross one direction of traffic at a time. Island at the centreline of roadway, at an intersection, or mid-block — usually constructed of concrete kerb, infill with pavers, or landscaping. Generally no or minimal reduction in vehicle speed but good increase in crossing opportunities for pedestrians.

**Speed table**
A long hump with a flat space in the middle, long enough to accommodate an entire wheelbase (or more). Often combined with a textured surface. May also be used as a raised pedestrian crossings (often situated at intersections).

**Speed bump**
A short, aggressive, rounded hump, spanning the width of the road — suitable for entrance/exit to carparks, esplanades, and service lanes etc ... less suitable for use in residential streets.

**Speed humps**
A vertical deflection device with a parabolic profile that is less aggressive than a speed bump — can be used on residential streets. Speed humps (generally) are predictably effective at reducing vehicle speed. Bump size and bump spacing affect vehicle speed most. Shorter and closer bumps have the greatest speed reduction.

**Speed cushion**
A narrow hump, not spanning the width of the road, forcing cars to drive over them with one wheel, but allowing vehicles with a wider axle, notably emergency vehicles, to straddle them and drive unhindered. Rubber speed cushions can be used in place of asphalt speed humps or speed cushions as a more visible, easier to transport, and possibly more cost-effective alternative. Rubber speed cushions may have less durability than hard infrastructure treatments and rubber installations may be perceived to have poor aesthetics.

**Surface texture**
Changing the surface material or texture (for example, the selective use of cobblestone) and/or colour.

**Cyclist bypasses**
Cyclist bypasses are generally appropriate where there are: single-lane devices, road narrowings, and devices with abrupt changes in vertical alignment (platforms and ‘speed bumps’). Bypass facilities can often be constructed using the original carriageway surface. Other measures that may be appropriate are: path links at road closures, contra-flow lanes or path links at one-way devices (short cuts).

**Radar speed signs**
Radar speed signs are an interactive sign, generally constructed of a series of LEDs that displays vehicle speed as motorists approach (as installed at several sites around Christchurch). Radar speed signs can result in consistent but modest reductions in the 85th percentile speed, as well as meaningful reductions in the speed of vehicles traveling in excess of the limit (while not interfering with the progress of the majority of traffic that is already traveling at or below the speed limit).
A cycle lane
A lane reserved for the exclusive use of cyclists, except that motor vehicle drivers may use the lane to access parking or to turn at intersections or driveways (kerbside cycle lane shown, may also be adjacent to motor vehicle parking (car-side)).

Buffered cycle lane
A cycle lane with a buffer space separating the lane from an adjacent motor vehicle travel lane and/or parking lane.

Protected cycle lane SBF
A cycle lane at carriageway level physically separated from a parking lane or other traffic lane by a raised kerb, bollards or other vertical feature.

Cycle path SBF
A facility physically separated from motor traffic and intended for the exclusive use of cyclists. If in a road corridor, it is at a different level than the carriageway.

Danish cycle track SBF
A cycle path higher than the adjacent road and lower than the adjacent footpath, separated from each by kerbs.

**SBF = Separated bicycle facility**

Drawings copied and adapted from: Lieswyn et al. (2012)
Carriageway
Shoulder

Sealed shoulder
That part of a sealed carriageway to the left of an edge line.

Bus lane
A lane reserved by a marking and/or sign for the use of buses. In most circumstances cyclists are permitted to use bus lanes when they are located next to the kerb (Austroads, 2014)

Cycle bypass
An example of a satisfactory bypass of a speed table in a residential street where the motor vehicle volume does not justify a cycle lane.

Vertical edge marker
An example of a vertical edge marker to define a cycle lane (CCC, 2013).
Figure 15: A shared path adjacent to a suburban segment of SH73 (25,000+ vehicles/24hr), Curletts Road, Christchurch

This shared path is essentially a ‘footpath’ with addition of signage. It is located alongside the carriageway with no additional separation, and has no separation from the property boundaries resulting in poor intervisibility (sight angles) at the many driveways (vegetation and high fences reduce intervisibility further). The level of service for cyclists is poor and the potential for interference by other path users demands slower speeds.

Photo: David Brinson, 2016

Protected cycle lanes

A protected cycle lane (separated bicycle lane) is not accessible to cars except for driveway access. The protection may be provided via raised kerbs, flags, bollards, landscape planters, or other vertical elements (Figures 16 & 17 show two different versions of kerb protection). Consideration should be given to the durability of vertical elements employed. One-way and two-way protected cycle lanes are possible (although two-way protected cycle lanes introduce additional complexities at intersections). Protected cycle lanes can offer a low-stress environment that can be attractive to many cyclists. In comparison to a shared path, a two-way protected cycle lane is further from the nearest property boundary and therefore offers better intervisibility between cyclists and motor vehicle drivers exiting a driveway.

Figure 16: A paved separator kerb protected cycle lane, Tuam St, Christchurch CBD

The above figure shows a good example of a protected cycle lane, using kerbs and a sufficiently wide paved separator. Car parking is provided to the carriageway side of the lane and car parking is punctuated at driveways by landscaping build-outs. The physical protection and smooth surface provide cyclists with a high level of service.

Photo: David Brinson, 2016
Figure 17: A kerb and painted buffer protected cycle lane, Ilam Rd, adjacent to the University of Canterbury

The figure shows a protected cycle lane of similar lay-out to Figure 16, however the physical separation is mainly provided by single width low concrete kerb only — apparently prone to damage caused by vehicles parking and manoeuvring.

Photo: David Brinson, 2016

Mid-block infrastructure exemplar

As discussed previously (p. 32), the type of infrastructure that might be implemented will vary widely depending on the road’s classification (i.e. the function of the road — the degree to which it serves ‘link’ verses ‘place’ functions). Figure 18 shows a ‘state of the art’ and well featured road section on a ‘high link-function’ road corridor. As an example, this road corridor (the McCormacks Bay causeway segment, Christchurch) provides almost exclusively ‘link’ functions and, resultantly, each relevant street activity has been afforded near optimal levels of space. Usually, however, a proportion of space is allocated to both link and place functions (incorporating car parking, driveways, shops etc). In some cases, there may be insufficient space to accommodate even the minimum levels of provision; and the best (or only) solution is likely to be to downgrade either the link or place function of that street segment. The example below provides all users with high levels of travel time reliability, resilience, optimal speeds, safety (separation), high travel quality and aesthetics, and good accessibility.

Figure 18: McCormacks Bay Causeway, Main Road Mt. Pleasant – Redcliffs, Christchurch

Post-earthquake redevelopment of the McCormacks Bay Causeway, Main Road Mt. Pleasant – Redcliffs, Christchurch: features include a high quality smooth surface 4m wide separated two-way shared path, tactile ground surface indicators and pedestrian refuges at crossing points (not shown in photo), full bus embayment, cycle lanes in both directions (green painted surface at intersections (not shown in photo), painted bicycle stencils, no vehicle parking, painted central median strip, landscaping and good aesthetics (landscaping features are of limited height to permit one-off and/or emergency oversize loads to be transported over this critical link between the City and the port of Lyttelton).

Photo: David Brinson, 2016
Intersection treatments for cyclists and pedestrians

**Note:**
— See also ‘Manual of traffic signs and markings’ (MOTSAM) - Part 2: markings’ NZTA (2009) Part 2 Section 2.10 and,
— Cycling Aspects of Austroads Guides Section 9.3. As MOTSAM is progressively being replaced and superseded by the ‘Traffic control devices manual’ (TCD), please refer to the current version of MOTSAM from the NZTA website.
— Specific advice is provided in MOTSAM, the various Austroads guides and under the Cycling Aspects of Austroads Guides for (amongst other things): roundabouts, traffic Signals, advanced Stop Boxes (ASBs) and hook Turns.

Table 7 (page 55) lists and describes a number of the most common intersection treatments that aim to improve cycling and pedestrian LOS and safety. The advantages and disadvantages of selected infrastructure types are discussed in the text, and specific comments are provided as necessary regarding the suitability of certain types of infrastructure for novice/experienced cyclists including children, and for pedestrians. The table is based on existing guides and design manuals, New Zealand legislation and the collective opinions of a range of cycling and pedestrian facility planners and commentators. The table does not comprise a full design guide, however further information is available in the cited literature. Following the table, a series of figures, photographs and diagrams are provided to illustrate the different types of infrastructure.

**Key principles**
The goal of safety-oriented intersection treatments is to accommodate cyclists and pedestrians safely, with a reasonable LOS, and at a reasonable cost, within the available constraints of the road corridor. The key planning principles relate to the type of intersection control and the provision of adequate space. The design should ensure that: the intersection performs efficiently; it is as far as possible suitable for cyclists of basic competence; all normal manoeuvres are possible (particularly right turns including hook turns, see below); the conflict area between through-cyclists and left-turning traffic (especially heavy vehicles) is managed; cyclists and drivers know where cyclists are expected to be on the road; the intersection type/treatment is consistent with mid-block facilities on approach and departure; and there is adequate provision for pedestrians.

**Types of Intersection**
The types of intersections found on the New Zealand road system can be broadly categorised as:

- At-grade intersections
- Grade-separated intersections (interchanges)

The basic forms of at-grade intersection may be:

- Three-legged (e.g. T-intersection)
- Four-legged (e.g. cross intersection)
- Multi-legged intersection

Within these basic forms an intersection may be:

- Signalised
- Unsignalised
- Roundabout

Within these basic forms an intersection may be sub-categorised as:

- Channelised (i.e. providing traffic islands and/or medians) to develop specific types of intersections (or alternatively unchannelised)
- Flared, to provide additional through and/or turning lanes or unflared (Austroads, 2009b).
Selection of an appropriate intersection treatment in any given situation can be complex and is beyond the scope of this document, however the above hierarchy can be used to compare cycling infrastructure proposals with/across the basic forms and intersection types (refer to Austroads, 2013, p. for more guidance).

The provision of the safest practicable treatment is utmost in all situations. However, many other factors, some of which are not related to road safety or operational performance, may influence the type of treatment adopted at a particular site. In addition to safety, the selection process of an appropriate intersection type and treatment may include consideration of: capacity, delay and level of service (generally and for specific road users); the overall planning philosophy and policy objectives; traffic management strategies or objectives for the road network or corridor generally; compatibility with adjacent intersection treatments; the topography at the site and the natural and built environment; and economic considerations. The overall aim is to provide a safe and cost-effective intersection treatment, within the constraints that may exist. The relative safety and needs of all road users, particularly pedestrians (including people with any impairment) and cyclists, should be considered, as their needs may be a significant factor in the choice of treatment and type of traffic control adopted.

Road user requirements for arterial road signalised approaches and within intersections

Pedestrians
Pedestrian marked foot crossings should be considered across all approaches of signalised intersections. Marked foot crossings should be located to minimise the potential for jaywalking. Medians should provide adequate pedestrian storage where a staged crossing is adopted. Pathways through medians and intersections should be clear of obstructions such as road furniture to enable safe and comfortable passage by pedestrians (including wheelchairs). Where pedestrian flows are very high, storage areas should be designed to provide adequate stopping sight distance and to maximise the capacity (pedestrian flow) of the pedestrian crossing, taking into account the various pedestrian characteristics and needs. The network must provide for pedestrian desire lines and should provide for the convenient, comfortable and safe movement of pedestrians through and sometimes within large intersections.

Cyclists
Bicycle lanes at intersection approach and departure should be provided where:

- the approach is on a designated bicycle route
- bicycle lanes are marked mid-block
- squeeze points exist for cyclists and it is feasible to develop sufficient space for the bicycle lane
- the layout of the intersection results in high traffic volumes and/or relatively high speed
- Where appropriate, consideration should be given to the provision of an exclusive lane for right-turning cyclists, placed between the right-turn lanes and through lanes for motor

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44 As a guide, a bicycle lane should be considered where a road carries or is likely to carry more than 3000 vehicles per day and/or a significant percentage of heavy vehicles.
consideration should also be given to the manner in which right-turning cyclists may gain access to the bicycle lanes.

The separation of pedestrians and cyclists from motor vehicles at intersections is generally achieved by one of three methods: at-grade (where two or more routes meet at the same vertical level and various intersection treatments are used to provide separation); grade separation, where the separation of pedestrians and cyclists from other road users is achieved by the use of difference in heights (e.g. an overpass or an underpass) and; temporal separation between motorists and cyclists (as achieved by signals) (NZTA, 2008).

Note: For road design options and examples of bicycle lanes at signalised intersections, refer to the Austroads Guide to Road Design: Part 4A (Veith, 2010).

Table 7: Definitions of Intersection treatments for cyclists and pedestrians

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition of Intersection treatments for cyclists and pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paths and foot crossings</td>
<td>Paths provide the network for pedestrian movement on the approaches to intersections and sometimes within large intersections. While paths are essentially a mid-block treatment, they link to and beyond the marked foot crossings at signalised intersections. To be effective the network must provide for pedestrian desire lines and orient pedestrians to correctly navigate intersections.</td>
</tr>
<tr>
<td>Raised-platform/Raised Bicycle Priority Crossing</td>
<td>Raised-platform bicycle and pedestrian priority crossings provide a safe crossing facility for cyclists travelling on off-road paths. This crossing reduces cyclist travel time (by reducing delay at road crossings) whilst improving cyclist safety (improved visibility) at busy roads. The crossings are characterised by a raised platform that is flush with the level of the cycle path. White line marking and signage (“Give way”) warns motorists of the priority cycle crossing while line marking and signage (“Road ahead”) warns cyclists of the road crossing (See Figure 22).</td>
</tr>
<tr>
<td>Storage areas</td>
<td>Medians should provide adequate pedestrian storage where a staged crossing is adopted. The desirable minimum width is that necessary to accommodate a pedestrian with a pram or a bicycle. At left-turn islands and other traffic islands, designers should provide an adequate pedestrian storage area with pathways clear of obstructions. Some form of pedestrian protection may be required in some instances.</td>
</tr>
<tr>
<td>Barnes dance</td>
<td>In CBD areas a separate special pedestrian (‘scramble’) phase may be provided in which case the entire intersection is allocated to pedestrian movement each traffic signal cycle.</td>
</tr>
<tr>
<td>Pedestrian crossing</td>
<td>Pedestrian crossings could either be considered a mid-block treatment or a type of ‘intersection’. As the name suggests, pedestrian crossings are generally for the use of pedestrians and dismounted cyclists. However, the ACT Government has commenced a two year trial of riding across pedestrian crossings that commenced on 1 November 2015. The change to allow cyclists to ride across crossings is intended to provide amenity for cyclists, without compromising safety for cyclists and any other road user.</td>
</tr>
<tr>
<td>Tactile Ground Surface Indicators (TGSi)</td>
<td>Tactile Ground Surface Indicators (TGSi) enable visually impaired pedestrians and people with full vision to detect street crossing points, bus stops, and hazardous surfaces or grade changes (warning and orientation functions). TGSis provide a distinctive surface pattern of truncated domes, cones or bars detectable by long cane or underfoot. Warning and directional TGSi can be readily retrofitted in many situations.</td>
</tr>
<tr>
<td>Cycle lane at signalised intersections</td>
<td>The placement of these facilities is complex, however general guidance is provided in ‘Manual of traffic signs and markings (MOTSAM) - Part 2: markings’ NZTA (2009). The section three ‘Intersection pavement markings section 3.18.12 cycle lanes at signalised intersections’ figures 3.36 and 3.37 show appropriate transitions of cycle provision between midblock and intersection locations. The aim is to achieve continuous provisions for cycling. Kerbside cycle lanes must NOT be used where an exclusive left turn lane exists.</td>
</tr>
</tbody>
</table>

Cycle lane on approach and/or within roundabouts
Not recommended in New Zealand (see discussion below)

Protected cycle lane on approach to roundabouts
A protected cycle lane, not accessible to cars, and located on the approach and left-turn exit of roundabouts to prevent cycle lane encroachment. The protection may be provided via raised kerbs or other vertical elements. Consideration should be given to the durability of vertical elements employed.

Kerb ramps
The provision of a gently graded and smooth invert at the gutter is a vital design feature for the safety and comfort of all path users, including cyclists (Figure 10) (Andersen et al., 2012; Austroads, 2009, 2014). In addition, the width of the ramp should match the width of the path, where cyclists need to turn left from the road onto the ramp, or from the ramp onto the road, a satisfactory turning radius (or skew) should be provided, and in some cases flatter kerb ramps of 1 (vertical) in 15 (horizontal) should be considered to provide more efficient and comfortable movement for cyclists between the road and the ramp (Austroads, 2009).

Traffic Signals including cyclist signals
In New Zealand, at intersections without a separate cyclist signal, cyclists have to use the motor vehicle signal. Arrow signals apply to all road users who wish to travel in the direction the arrow indicates. Specific cyclist signals are used in New Zealand but they are not very common. At intersections where cycle lanes of paths continue to the stop line, a separate cyclist signal may be installed (or separate signal light in addition to the main bank of lights/signals). In this way cyclists can have their own signal phase, wholly or partially. Cyclist signals can be used for pre-green for cyclists several seconds before motor vehicles. This can be used to give a separate right turn phase for cyclists, pre-green for straight ahead, ‘free left turn’ or some combination of specific or pre-phases. A ‘head start’ in relation to motor vehicles can render cyclists more visible and reduce cyclist-motor vehicle conflicts.

Parking (restriction of)
Parking is relevant to intersection treatments as the allocation of space to parking on signalised intersection approaches and/or departures can have a substantial impact on traffic operation and performance and pedestrian and cyclist safety. Clearways are often used on arterial roads to maximise capacity during peak periods. Parking should be restricted on the immediate approach to intersections in order to utilise the capacity of the left lane (or use clearways at peak periods) and parking must not impede the required stopping sight distance to pedestrian crossing facilities and pedestrian storage areas.

Special lanes (approaches, through and/or departures of intersections), a ‘queue jump’ lane
Typically, a bus lane at an intersection simply becomes an extension of the mid-block lane, as an additional lane on the approach, or may serve as a queue jump lane that is long enough to enable buses to pass a queue of general traffic and obtain an early start at traffic signals, however, where space is constrained it may be necessary for cyclists to share the lane with buses, possibly creating competition for the same space on the carriageway. Bus lanes (and by extension the space they occupy at intersections) should be signed, marked and delineated in accordance with the relevant standards. At sites where space is available it is preferable to provide a separated bus lane and bicycle lane treatment or a high-standard off-road bicycle path or shared path. A stationary bus waiting or ‘held-up’ within an approach side lane can adversely reduce the sight distance available to other road users and may prevent cyclists accessing a safe queue position (i.e. reaching their advanced stop line or stop box). Bus priority may involve more peak period bus lanes and priority traffic signals for buses, along priority routes and this has the potential to impact negatively or positively on cycle safety and LOS depending on the specific treatments.

Advanced stop box (ASB)
An area in front of a general traffic lane on an approach to a signalised intersection to raise awareness of cyclists by motorists and to give priority to cyclists over other traffic for a particular manoeuvre (NZTA, 2008). ASBs and ASLs have been shown to improve cyclist positioning behaviour. The placement of these facilities is complex, however general guidance to their placement is provided in MOTSAM (NZTA 2009). ASB and ASLs should be coloured green in NZ. Traffic and cycle lane combinations greater than 5.0 m should be avoided (Koorey & Mangundu, 2010).

Advanced stop line
A lane limit line for a cycle lane that is extended beyond the limit lines of other adjacent lanes on an approach to a signalised intersection (NZTA 2009).

Hook Turn Facility
A marked box within the intersection which provides a waiting space for the second stage of a two-stage right turn made from the left side of a carriageway. The Road User Rule amendment (Ministry of Transport, 2009) clause 2.5A formally introduced the hook turn rule to New Zealand and states that a cyclist may enter an intersection by making a right turn or a hook turn. The manoeuvre does not require a marked hook turn box. However, hook turn boxes should be provided to assist cyclists with this manoeuvre as the manoeuvre is unique to cycling and may not be intuitively adopted by all cyclists without the guidance provided by the painted markings. By cyclists keeping left, a hook turn reduces conflict between cyclists and motorists.

Bent-out, Straight and Bent-in pedestrian/cycling side road intersection treatments

46The New Zealand Road Code for Cyclists describes the hook turn manoeuvre for turning right at a signalised intersection at https://www.nzta.govt.nz/resources/roadcode/cyclist-code/about-cycling/cycling-through-intersections/

47In 2002 the first hook turn trial was undertaken in Christchurch at the Greers Rd / Memorial Avenue intersection near Burnside High School.
There are three types of treatment available for the design of path crossings of side streets, a design where the path approach is bent-out (i.e. is deviated away from the major road), a design where the approach is straight, and a treatment where a one-way bicycle path is deviated to become an on-road bicycle lane. The first two types of treatment may be applied to bicycle paths or separated paths.

**Structures**

A number of structures are used in association with cycle provision, such as bridges, underpasses and overpasses. Site topography may favour either a bridge or an underpass. Because structures are expensive, the needs of cyclists and others must be properly identified, particularly in relation to: constructing a motorway, planning new residential areas, and designing a structure (opportunities for retro-fitting structures are probably limited).

**End-of-trip facilities**

End-of-trip facilities (such as secure parking, lockers and showers) and trip facilities such as shelter, water and toilets are important infrastructure for cyclists.

Source: adapted from (Lieswyn et al., 2012), (Austroads, 2014a), (NZTA, 2008), and (Andersen et al., 2012).

**Common intersection treatments on urban roads**

On bicycle routes a ‘head start area’ should be considered to allow for cyclists to wait at the stop line at a position in advance of the motor vehicles, and this treatment is relatively common in New Zealand (Figure 19). This facility ensures that cyclists waiting at the red light are visible to the first driver in the queue, particularly drivers of commercial vehicles that may have their view of cyclists impeded by the height of the left door of the vehicle.

![Figure 19: Appropriate use of advances stop box with approach cycle lane (NZTA, 2009b)](image)

**Note:** refer to NZTA, 2009 section 3 p.66 for different appropriate and other not appropriate layouts for advanced stop boxes. For more examples and details please see Austroads (2014) Cycling Infrastructure Selected Case Studies (Austroads, 2014b).

In New Zealand, cyclists are also permitted to undertake a ‘hook turn’ at intersections instead of a conventional right-turn (Figure 20). This option can be used by cyclists at signalised intersections (with or without a painted hook-turn stencil) where they can complete the manoeuvre with a green signal, after waiting at the intermediate corner. Provision of a storage area at the corner is not universally applied in New Zealand but additional space may be provided by setting back the pedestrian crosswalk lines and stop line on the intersecting approach. This ‘head start area’ may be marked with bicycle logos. Figure 21 shows a hook turn facility with and without exclusive left turn lane (also showing advanced stop lines on cycle lanes). While the hook-turn manoeuvre is optional in New Zealand (with or without a painted stencilled box), in some countries it is compulsory (e.g. 

![Figure 21: Hook turn facility with and without exclusive left turn lane](image)
Denmark where the Transport Act specifies that cyclists may not follow the motorists’ left [i.e. right in New Zealand] turn arrow.

Figure 20: Diagram of the hook-turn manoeuvre (Christchurch)

Shows the layout and the hook-turn manoeuvre at the first hook-turn trial site at the Memorial Avenue and Greers Road intersection in Christchurch. The hook turn offers a solution to the right-turn problem because it allows cyclists to make their right turn from (in this case) Memorial Avenue into Greers Road whilst keeping left at all times, during two green light phases. In the first green phase cyclists on Memorial Ave cross Greers Road to a special marked area for cyclists within the intersection. This area, marked in red (now green), provides a space where cyclists can wait for the second green phase to cross Memorial Avenue and continue along Greers Road towards Burnside High School.

Figure 21: Hook turn facility in front of an exclusive left turn lane (also showing advanced stop lines on cycle lanes) (NZTA, 2009b)

Note: refer to NZTA, 2009 section 3 p.65 for different layouts for hook turn facilities.
Raised-platform bicycle priority crossings (Figure 22) are becoming more common in New Zealand and they provide a safe crossing facility for cyclists travelling on separated paths. This crossing type reduces cyclist travel time (by reducing delay at road crossings) whilst improving cyclist safety (improved visibility) at busy roads. The crossings are characterised by a raised platform that is flush with the level of the cycle path. White line marking and signage ("Give Way to Cyclists") warns motorists of the priority cycle crossing while (in some cases) line marking and signage warns cyclists of the road crossing.

![Figure 22: Raised-platform/Raised Bicycle Priority Crossing, Matai St. Christchurch](image)

The two-way separated Matai Street East Cycleway (path) provides a safe cycle connection and manages vehicle flows as they approach the Uni-Cycle Deans Avenue crossing. The cycle path increases the appeal of cycle journeys to and from the university, schools and into the CBD. Priority is given to cyclists at this raised, two-way crossing of Matai St. via “Give Way To Cyclists” signage.

Photo: David Brinson, 2016

**Types of crossings of side roads**

There are three main types of treatment available for the design of path crossings of side streets, a design where the path approach is bent-out (i.e. is deviated away from the major road), a design where the approach is straight, and a treatment where a one-way bicycle path is deviated to become an on-road bicycle lane. The first two types of treatment may be applied to bicycle paths or separated paths. For cases involving two-way paths the priority can be either be allocated to the path or to drivers on the side road. Give-way signs and holding lines should be used to clearly define priority and regulate the movement of cyclists and motorists.

**Bent-out treatment**

Where there is sufficient space in the road corridor, bicycle paths can be bent away from the parallel road at its intersection with the side road. The principal reason for bending out is to allow storage space for vehicles turning into the side road. Therefore, bending out is only necessary (should be used) where it is desired to give path users priority. Figure 23 shows a bent-out treatment on a bicycle path which allows storage space for vehicles entering and leaving the side road. The treatment may be suitable where:

- few large heavy vehicles (e.g. semi-trailers) use the side road
- volumes on the side road are low
- speed on the major road and side road is ≤ 60 km/h (Austroads, 2009a, 2009b).
**Bent-in treatment**
This treatment provides for a one-way bicycle path to transition into an on-road bicycle lane, thereby enabling cyclists to have priority across the side street. It should not be used for two-way paths because of the head-on conflict that would arise between cyclists and motor vehicles. This treatment is shown in **Figure 24**. The bent-in treatment has the advantage of providing greater visibility of cyclists for drivers at the intersection and should enable drivers to better anticipate the movement of cyclists. It also easily provides for cyclist priority at the intersection and for the transition from path to on-road lane to be physically protected. These treatments are suitable only for experienced cyclists who have the skill and maturity to safely enter and ride in traffic. They are not suitable for paths used by children on school routes. If a pedestrian crossing is provided in the side street it should be located at least a vehicle storage length form the side street holding line.

**Straight**
The straight crossing option on a separated two-way bicycle path provides for both cyclists and pedestrians to have formal crossings of the side street controlled by pedestrian crossing signs and give way signs respectively. To maintain better route continuity and rider comfort this treatment may be placed on a platform. The treatment is suitable where traffic volumes in side streets (i.e. residential streets) are low (where side streets have higher volumes a bent-in treatment may be appropriate). In instances where pedestrian and cyclists volumes are relatively low, priority will often be given to motor vehicles. The main benefit of a straight crossing relatively close to the major road is that the path has a higher visibility for road users where space for a bent-out crossing is not available. It is important therefore that the path is placed close enough to the edge of the major road to maintain visibility (a left-turn auxiliary lane is compatible with this design).
Figure 23 shows an option for a bent-out crossing on a separated two-way bicycle path (but not shared path). The treatment provides for both cyclists and pedestrians to have formal crossings of the side street controlled by pedestrian crossing signs and give way signs respectively. To maintain better route continuity and rider comfort this treatment may be placed on a platform. Variations on this theme include bent-in and straight treatments and these are discussed in *Austroads guide to road design: Part 4: Intersections and Crossings — General* (Austroads, 2009b, p.88).
Roundabouts

Pedestrians
It is emphasised that with most roundabouts special crossing facilities will not be necessary (Austroads, 2013). Generally, the installation of well-designed splitter islands of sufficient size to hold and protect pedestrians allows them to cross only one direction of traffic at a time. This should result in pedestrians being able to move more safely and freely around the intersection than was the case before the installation of the roundabout. On small roundabouts in local streets a cut-through of splitter islands at pavement level or a painted island may be appropriate. However, where pedestrian volumes are high, consideration should be given to the use of an alternative intersection treatment (particularly where there are schoolchildren or elderly people crossing) (Austroads, 2013, 2014a).

Cyclists – Important changes to roundabout design recommendations
Guidance on the use and design of roundabouts including bicycle treatments is provided in the recent Austroads publication Guide to Road Design Part 4B: Roundabouts (Austroads, 2015). This Guide incorporates updated design principles in alignment with recent research in the area of cyclist safety, based in part on crash analysis data from several New Zealand and Australian intervention sites (Wilke et al., 2014). While roundabouts are a relatively safer form of intersection for motorists than signalised intersections, many studies show that they result in a higher rate of crashes for cyclists. This is especially so in countries such as the UK, Australia and New Zealand, where the design philosophy for roundabouts tends (or has tended) to be oriented towards capacity (this is more pronounced at larger roundabouts) (Wilke et al., 2014). It is generally accepted that multi-lane roundabouts present a significant challenge for experienced and inexperienced cyclists alike, and multi-lane roundabouts may cause significant stress and be a deterrent to riding.

In an effort to address this, some road controlling authorities in Australia and New Zealand have followed some European and UK examples and implemented bicycle lanes up to, through and departing roundabouts. However, there is conflicting evidence about the net safety effects of such treatments. Studies have tended to suggest that bicycle lanes at roundabouts may decrease actual safety and previous guidelines have reflected this concern (Austroads, 2014a; NZTA, 2008, 2009a). The apparent decrease in safety may be due to the potential for bicycle lanes to increase motor vehicle speeds by reducing deflection, with a consequent reduction in time for drivers to observe and react to cyclists. Bicycle lanes may also encourage cyclists to adopt lane positioning which increases the probability of conflict with motor vehicles (Wilke et al., 2014). Conventional right-turning manoeuvres at multi-lane roundabouts are a particular problem for cyclists because of the nature of their interaction with motorised traffic.

A Safe System approach
A Safe System approach is recommended, based on the components safer roads and safer speeds. One of the key recommendations for making roundabouts safer for cyclists is achieving equitable speeds (desirable = 25 km/h; maximum = 30 km/h). Achieving equitable speeds between vehicles and cyclists should be considered so that cyclists can comfortably ‘claim the lane’ and mix in with the traffic flow (contrary to idea behind circulatory cycle lanes). Where this speed regime cannot be achieved, cyclists should ideally be provided for so that they don’t have to enter the circulating...
carriageway (Austroads, 2014a; Wilke et al., 2014). Equitable speeds might be achieved by a combination of geometric features, visibility management, and shared lane markings (Table 8).

**Summary of general principles for roundabouts**

**Low volume, low speed, single lane roundabouts**

- Specific provision for cyclists is not generally required at single-lane roundabouts on local streets with low traffic volumes (i.e. ≤ 3000 vehicles/day), where vehicle speeds are low (i.e. ≤ 50 km/h) and where the geometry encourages very low approach speeds (e.g. 20 km/h). Under these conditions, cyclists should be able to safely share the road/lane with general traffic.

**Higher volume, higher speed single and/or multi-lane roundabouts**

- Reduce the relative speed between entering and circulating vehicles
- Where circumstances require that a significant number of cyclists use a roundabout the approaches should be designed to cater for the lowest practicable approach speed (e.g. traffic enters at an approach angle that is approximately perpendicular to the central island).
- Minimise the number of circulating lanes
- Maximise the distance between approaches
- A separated cycle path, located outside the circulating carriageway, is the safest design when there are high vehicle flows (with uncontrolled cyclist/pedestrian movement across each approach leg)
- Consider the provision of signalised intersections instead of roundabouts on designated bicycle routes that cater for commuter cyclists
- Consider the provision of a path to provide a bypass of three-leg roundabouts for cyclists travelling across the top of a T-intersection.

**High-speed roundabouts**

Cycling and high-speed roundabouts create significant safety problems for cyclists: where cycling is to be encouraged and high speeds are desirable, there is no completely satisfactory alternative to grade separation (overpasses or underpasses). Retrofitting such designs to existing roundabouts is likely to be cost prohibitive in most locations. However, some at-grade treatments may be beneficial and cost-effective for retrofitting in many instances.

There are two main risks for cyclists at high-speed roundabouts:

1. **On the approach or the departure, cyclists may end up under the wheels of trucks that are tracking too close to the kerb.**
   
   **Possible solution:** Although it prevents cyclists from claiming a central lane position early, the evidence presented by Wilke and colleagues’ trials (2014) suggests that on balance, physical separation on the approach and the departure might be useful to mitigate this crash type (as shown in Figure 25).

2. **Circulating cyclists are often overlooked by entering motorists. Evidence suggests that cyclists can make themselves more visible by claiming a central lane position—‘Claiming the lane’—but this not be possible when fast-moving traffic is present at the same time.**
Possible solution: The literature review evidence and roundabout trial evidence presented in Wilke and colleagues’ (2014) report points towards cycle lanes within the circulating carriageway having a detrimental effect on road safety, mainly because they discourage cyclists from claiming the lane. However, this evidence is still inconclusive and more roundabout modification trials are needed to obtain before-and-after comparisons.

Wilke et al. (2014) summarise that circulatory cycle lanes at high-speed roundabouts might do one of the following:

1. Have a negative effect on safety if they result in more cyclists tracking closer towards the splitter islands, or
2. Have a neutral effect on safety, as tracking is mostly unaltered, or
3. Possibly, slightly improve safety through increased visibility achieved by the application of colour.

Hence, for existing high-speed roundabouts, the recommendation is to consider physical separation on the approach and departure as per Figure 25 but not the circulatory cycle lanes shown. Further, if physical protection is not provided, then painted lanes should terminate 20m before the roundabout and cyclists then enter the roundabout as mixed-traffic.

![Diagram](image-url)

**Figure 25:** Retrofitted at-grade physical separation of cycle lanes on approach arm/left turns on a high capacity/speed roundabout

**Source:** Adapted from Wilke et al. (2014) as reproduced in Austroads (2014).
**Multi-lane roundabouts**

Multi-lane roundabouts usually carry high traffic volumes and have higher entry speeds than local street roundabouts and therefore create safety problems for cyclists. There is currently no (at grade) treatment that would assist cyclists to turn right safely through a multi-lane roundabout. It is therefore anticipated that only experienced cyclists will use this type of roundabout and whilst they may feel reasonably comfortable in selecting a gap and turning left and travelling straight through a multi-lane roundabout in the bicycle lane, they will generally find the right-turning manoeuvre challenging. Some cyclists will therefore bypass the right turn by using local streets or shared paths at the roundabout (where provided).

![Diagram of a roundabout](image)

**Figure 26: Crossing detail for a shared path adjacent to a multi-lane roundabout**

*Source:* (Austroads, 2015)

Bicycle paths or shared paths may be provided adjacent to roundabouts to provide safer passage for inexperienced cyclists and pedestrians. Where a shared path is provided at a multi-lane roundabout and bicycle lanes exist on the approach, the crossing treatment shown in **Figure 26** may be used. This treatment provides a crossing at road level as well as convenient connections between the bicycle lanes and the paths to encourage cyclists to use the shared path to negotiate the roundabout (lesser designs can link painted cycle lanes to the existing footpath using off-ramps, creating a shared footpath so that cyclists can exit the roadway to negotiate the roundabout).

**Table 8: Summary of pedestrian/cycling infrastructure features at roundabouts**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical separation on the approach and departure</td>
<td>✓</td>
</tr>
<tr>
<td>Circulatory cycle lanes</td>
<td>✗</td>
</tr>
<tr>
<td>Grade separation (overpasses or underpasses)</td>
<td>✓</td>
</tr>
<tr>
<td><em>Bicycle paths/shared paths adjacent to roundabouts with at-grade crossings on each leg, controlled if necessary</em></td>
<td>✓</td>
</tr>
</tbody>
</table>

*Note:* Many experienced commuter cyclists would consider that the use of an off-road path around a roundabout is unacceptable in terms of delay and risk (i.e. crossing the approaches and re-joining the traffic stream). It is in this context that commuter cyclists prefer to use the road network and it is therefore necessary to cater for cyclists at intersections, including roundabouts (Austroads, 2013). External perimeter paths should be considered for large multi-lane roundabouts but will generally result in a poor LOS for cyclists owing to crossing delays. Grade separation or conversion to traffic signals is strongly preferred over multi-lane roundabouts.
Public transport (Bus)

Introduction

Buses and bicycles are at opposite ends of the spectrum in terms of size (and visibility), mass and manoeuvrability, but they frequently operate in the same road space, especially adjacent to the kerb and at intersections. Buses can be an effective alternative to the private car for travel in New Zealand towns and cities, however they can come into conflict with other road users (particularly cyclists). Urban transport strategies (for major cities internationally) now focus more heavily on reducing, or at least reducing the growth in, private car traffic (for the range of social, environmental and economic reasons already discussed).

However, buses are often given priority almost as a matter of course, and proponents of active transport modes suggest that this ‘default’ should be routinely challenged (DETR, 2001). In the planning/proposal process, a comparative assessment should be made of the relative impacts of bus-priority, cycle-priority and equal-priority. The main factors that are important to public transport are safety, LOS, volume of use, role in the network, impact of delays due to lack of priority and the adequacy of alternative routes, and these should be taken into account and balanced against other ‘active transport’ priorities (NCHRP, 2008). It is important to note, that “percent heavy vehicles” is a strong determinant of cycling LOS (NCHRP, 2008) and safety, and, not only are buses heavy vehicles but they are typically numerous and they stop/start frequently on routes that are not necessarily well suited to heavy transport. Ideally, for the advancement of the active modes (walking and cycling), public transport (buses) should not be given priority at the expense of the former, and every effort should be made to explore appropriate and balanced alternatives. While new dedicated bus facilities in exclusive rights of way can provide opportunities for creating new cycle and pedestrian facilities (e.g. bicycle parking, accessibility of bus stops, enhancing the route options), there is also the risk of increasing severance and reducing the convenience of cycling if adequate crossing opportunities are not provided. Contractual imperatives for bus operators likely require operators to meet certain standards and may expose operators to financial penalty for late-running. Even without financial penalties, there are commercial and customer service drivers to ensure consistent and timely service provision (Austroads, 2000).

Careful planning that considers both bus and bicycle can minimise the extent to which potential conflict occurs. One possible solution is the development of a consistent ‘theme’ approach to

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48 At the strategic planning level, the interaction of bikes and buses is most frequently seen in terms of the potential of the bicycle, as a feeder mode, to expand the catchments for public transport.

49 For example thematic approaches such as London’s ‘Red Routes’: major roads on which vehicles are not permitted to stop (extends to stopping for loading or unloading, and to boarding or disembarking from a vehicle, except for licensed taxis) and red routes are mainly used on major bus and commuting routes.
provision for cyclists, where priority measures are clearly aligned to different types of bus routes (i.e. bus vs cyclist priority is clearly differentiated between road types/route types based on their Link-Place functions).

**Increasing safety**
From a public health perspective, improved safety for active transport participation arguably requires a shift of focus. This shift would involve an unweighting of the strategic priorities (e.g. expanding the catchments for public transport) and a shift towards more in-depth consideration of active transport LOS and objective safety, specifically, minimising the degree to which public transport (bus) impacts negatively with cycling on any given roadway segment.

In terms of planning and design guidance, most attention has been paid to the ways in which bikes and buses co-exist along the roadway. Key issues in this respect include:

- the extent of separation (if any) between bikes and buses, and
- the treatment at bus stops – with respect to bikes passing buses and potential conflict with boarding/discharging passengers.

With regard to safety, generally, bus-cyclist crashes are characterised by a high proportion of angular crashes at non-intersection locations. In particular, a substantial proportion of angular crashes are related to lateral movement of buses in the roadway. **Table 9** outlines the most common bus-bike conflicts within a typical road network.

**Table 9: Regular and difficult interactions between buses and cyclists**

<table>
<thead>
<tr>
<th>Blind spots and swept path conflicts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus turning movements can pose ‘blind-spot’ and ‘swept-path’ issues; especially where the bus is making a left turn from a dedicated left-turn lane and lane geometry is inadequate for the bus to remain totally within the turning lane. This especially important for cyclists travelling straight through the intersection as they will usually be close to the left of this lane.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Roundabouts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundabout design is a key issue for buses and bicycles both in the context of their interaction, and individually. The appropriate solutions for one might compromise safety and convenience for the other. The issues may also vary depending on the size of the roundabout, i.e. those with only a single circulating lane compared to those with two or more. Solutions Include ‘bus bypass’ options.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Signalisation conflicts (bus priority lights)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of ‘B’ bus priority lights can cause conflicts in/around a bus lane (which may be used by cyclists): a bus driver may be unaware of a cyclist still in the intersection (e.g. when completing a Hook Turn as the cyclist may not arrive until after the lights for turning/intersecting traffic have turned green).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Young or inexperienced cyclists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young and/or inexperienced cyclists are least able to cope with complex traffic environments. Such manoeuvres as safely merging into the general traffic lane to pass a stopped or stopping bus are likely to be beyond the skill and speed capabilities of young and/or inexperienced cyclists (potentially placing young and/or inexperienced cyclists at great risk).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bus exchange entry and exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>The entry and exit points for bus stations inevitably have high concentrations of bus movements often in complex environments involving turning and other vehicle manoeuvres.</td>
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</tbody>
</table>

Source: (Austroads, 2005)

**Planning principles (Bus)**
In addition to improving existing situations for cyclists, an important focus for transport planning is to ensure that new initiatives to improve the operating environment for public transport do not inadvertently make things worse for cyclists. Initiatives to provide priority for buses in the road system are generally seen to provide an overall benefit to the community, however, priority features for buses can make the cyclists’ position worse. Such public transport upgrading should include
appropriate mitigation or upgrading measures for cyclists as an integral and necessary part of such a project.

For many types of cyclists, the coexistence of cycle and major bus networks should be kept to a minimum, unless it is possible to provide visually- or physically separated facilities for cyclists. This is especially important for inexperienced and young cyclists. The key to this approach is ensuring that alternative routes for cyclists offer a significantly higher LOS (compared to one shared with buses), including consideration of distance. Consideration should be given to changing bus routes as well as cycle routes.

Continual changing of conditions for cyclists and other road users along a route fosters uncertainty and unpredictable behaviour, particularly at those places where conditions change. Such changes act as both real and perceived barriers to use by cyclists (which includes changes in lane width and tapers which may cause cyclists to swerve unpredictably). Such change points are likely to be hazardous in themselves, especially where sub-optimal treatments are imposed by, for example, road-space constraints and high traffic volumes. It is imperative that cyclists are provided with a continuously-accessible ‘path’ (of some type) for the length of the road/road segment (Austroads, 1999).

Where space is constrained it may be necessary to provide a wide kerbside bus lane that is wide enough for cyclists to share (Figure 30, page 72). At sites where space is available it is preferable to provide a separated bus lane and bicycle lane treatment or a high-standard off-road bicycle path or shared path. A bus lane simply becomes an additional lane on the approach to the intersection and should be signed, marked and delineated clearly in accordance with the relevant standards. Intersection treatments may include tapered entry markings and signage to create a ‘queue jump’ lane. The bus lane is usually located to the left of the road although where a bus route turns right at an intersection, a right-turn bus lane may be provided. Transit lanes for the use of high occupancy vehicles and buses may also be provided and shoulders on motorways, and motorway ramps, may also be considered for use by buses to bypass traffic queues.

The choice of treatment will depend on the user groups that have to be accommodated. If there is strong demand for commuting by bicycle an on-road bicycle lane is likely to be preferred. If design constraints prevent the provision of an on-road bicycle lane or cyclists are likely to be at risk on a high-speed road it may be preferable to provide a high-standard off-road bicycle path. If there are moderate demands for both bicycle travel and walking then a shared path should be considered. Designers should use the relevant guidelines to develop a treatment suitable for the particular site.


Facility design: bus station entry/exit

The entry and exit points for bus stations inevitably have high concentrations of bus movements often in complex environments involving turning and other vehicle manoeuvres. It is desirable for cyclists to be provided with a separate access route into modal interchanges, rather than to be required to use those points of entry (or internal road-space) where buses will be present. It may be desirable to have grade separation where the overall level of conflict is high. The manoeuvring room

50 For experienced and commuter cyclists, however, arterial roads, which often carry a substantial number of buses, will probably continue to form acceptable, logical and convenient cycle routes.
within bus stations is usually minimal, and cyclists should be kept away from those areas where buses might be manoeuvring or reversing.

**Bus stops**

Bus stops are usually situated on the left verge of a road, however, where a bus must turn right at a signalised intersection, the bus stop may be located some distance upstream from the stop line to enable the bus to access the right-turn lane; often a difficult manoeuvre. For this reason a bus stop may be incorporated into the approach and a separate signal bus priority phase provided to enable the bus to turn right from the left lane. The stop may also be located within a wide median, left-turn island or traffic island between left-turn lanes and through lanes. In some cases a bus stop may be provided on an intersection departure to suit a particular route and/or passenger demands (Austroads, 2009a, 2009b).

Bus stop location and design should take account of the extent to which buses stopping to pick up or drop off passengers will impede cyclists and other traffic (and vice versa). Cycle lanes and paths may increase the number of bicycle accidents at bus stops if no safety measures are taken. At bus stops without waiting areas, virtually all accidents are between passengers leaving the bus and passing cyclists (Andersen et al., 2012). Where the kerbside lane (whether a bus lane or a general traffic lane) is not wide enough for a cyclist to pass a bus safely, consideration should be given to a cycle bypass (Figure 27) or a localised widening of the lane to permit such passing (equivalent to a partial bus stop embayment) or full embayment of the bus stopping area.

There are three main options for the design of bus stops, each of which can have a distinct effect on the passage of cyclists and other traffic.

**1 Kerbside:** Bus stops unobstructed by kerbside activity are rare and it is usually necessary to find a means to sufficiently encourage motorists to keep the bus stop clear. A kerbside stop that allows the bus driver to pull up parallel and within 200mm of the kerb requires 26 metres of clear kerbside space (8m of approach manoeuvring space, 11m to park, and 4m to exit). This may include driveways. Stopping at kerbside, within the running lane results in the following:

- buses can pull away easily after stopping;
- there may be issues with parked cars, (if allowed);
- cyclists must go around the outside of the stopped bus, or wait (as must general traffic);
- there may be potential conflict if a bus and a cyclist are approaching a stop concurrently.

![Figure 27: A bus stop on a bus lane, with cycle lane bypass](Source: Christchurch City Council (2013))
(2) **Bus embayments/a bus lay-by:** A bus bay is an inset into the roadside to remove stationary buses from the traffic flow (Figure 28). Bus bays may provide a solution for routes with higher traffic flows and speeds as they provide minimal obstruction to passing traffic (including cyclists). Stopping within a bus bay results in the following:

- in mixed traffic, bus bays prevent confrontation accidents between cyclists and cars. Cyclists don’t have to look back and check for traffic then manoeuvre into the mixed flow to get around buses;
- buses have to merge to re-join traffic flow. This depends upon the goodwill of other drivers, despite the requirement to give way, cycles can easily continue past the stopped bus (as can general traffic);
- potential conflict with cycles as buses enter or leave the embayment.

(3) **Bus boarders:** bus boarders (Figure 29) involve a kerb extension to bring the footpath out to near the edge of the closest traffic lane (opposite design concept to bus embayment). Without the need for manoeuvring space, bus boarders are shorter than a kerbside stop. Bus boarders can include cycle bypasses to reduce impediments and improve safety for cyclists. Bus boarders can be effective in urban speed environments of 50 km/h or less with moderate traffic flows.

Bus boarders position the bus in the live traffic lane such that other vehicles must wait until the bus moves off. This may be appropriate on highly congested corridors where a bus may have a difficult time re-joining the traffic stream (and generally, vehicles are not shown to have appreciably increased trip segment times). Half width bus boarders are another variation on the theme and they will generally block the cycle lane (if present) but allow following traffic to pass (a cycle bypass can also be incorporated in

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Figure 28: Bus embayment, Main Road, Mt. Pleasant – Sumner, Christchurch

This full bus embayment is located adjacent to the generously proportioned three-lane carriageway, flanked by the 4m wide 6.5-kilometre long Ferrymead, Mt Pleasant, Redcliffs to Sumner Coastal pathway (multi-use, shared). The road corridor also includes cycle lanes in both directions. This design facilitates the free-flow of cyclists and general traffic, however buses can potentially encounter difficulty as they attempt to merge and re-join traffic.

*Photo: David Brinson, 2016*

Figure 29: A part-width bus boarder with cycle bypass

The photo (and diagram above) shows a ‘bus-boarder’ kerb extension used to minimise any problems for the bus re-entering the traffic stream. The extent to which this can be achieved is limited by the need to provide for a continuous lane for cyclists to use when no bus is at the stop. The degree of build-out needs to be such that there is not room for a motor vehicle to pass to the bus within the kerbside lane. The diagram shows a full width bus boarder (cycle bypass could be added).

*Photo: Glen Koorey*
the design). Positioning buses alongside the kerb at a bus boarder generally results in the following:

- easier boarding as the bus pulls up very close to the kerb (i.e. ≈ 25mm);
- faster boarding times allowing greater route efficiency;
- lower impact on competing kerbside demands such as car parking;
- improved visibility of waiting patrons as the sign is located closer to the traffic lane and out from behind parked cars and trees;
- additional footpath space where pedestrian flows are high; and
- opportunities for landscaping and improved amenity.

**Bus shelters**

Bus shelters that intrude on the travel space of cyclists on shared paths, either directly (i.e. encroaching on the path itself) or indirectly (reducing lateral clearances) will reduce the safety, convenience and comfort of the facility for cyclists. Bus shelters and other associated bus stop furniture should not intrude upon shared paths, either directly or indirectly.

**Bicycle storage facilities**

The Austroads Guide to traffic engineering practice (Austroads, 1999) recommends that bicycle parking facilities should be provided at common commuting and recreational destinations of bicycle trips, including railway stations, bus terminal and interchanges. Secure facilities (including hard standing and fixed racks) enhance the level of usage and integration between cycling and public transport, to the benefits of both (Andersen et al., 2012). The recommended approach for the provision of bicycle parking is to identify bus stops that meet the following criteria:

- a high proportion of longer-distance bus journeys,
- a bicycle catchment that is not served by adequate alternative public transport access with secure bicycle parking,
- active or passive surveillance to enhance security of parked bicycles, and
- suburban bus stations, and these should provide lockers, security and lighting.

Summarised from: *Bus-Bike Interaction within the Road Network, Austroads (2005)*

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51 Bicycle parking is not required at every bus stop, as the bicycle confers upon its rider the ability to travel substantially further to such an access point.
Increasing bus patronage

Bus use in Christchurch city has been in decline for a number of years: between 2006 and 2013 patronage fell from 5.1 percent to 3.7 percent of people who went to work on census day\(^5^2\), and overall bus use is reportedly still in decline despite a post-earthquake network review\(^5^3\). It has been suggested that much more could, and should, be done to improve bus services in urban Christchurch. Even with the flexible operating characteristics that buses offer, the main challenge is to serve the low residential densities and increasingly dispersed employment, education, shopping and other trip-generating activities which characterise post-earthquake Christchurch.

Although, in this case, the Canterbury earthquakes forced the radical and rapid relocation of trip-generating centres around Christchurch, the city is not unique in its move towards decentralisation. Many modern cities show similar trends and Thompson et al. (2012) conclude that the key problem that transit agencies face is that the central business district is no longer the primary centre of economic activity in many metropolitan areas.

Pushkarev and Zupan’s (1977) classic study of the relationship between the strength of the central business district, residential density, and transit ridership in the New York metropolitan area clearly illustrated that a centralised city structure is the most desirable structure, at least from a transport efficiency perspective. In addition, based on the large body of research from the 1960 onwards, the most appropriate strategy has been for transit agencies to focus their systems on the traditional central business district (or its closest equivalent) using a traditional ‘radial’ bus network design.

However, Thompson et al. (2012) suggest that in many cities, ‘traditional CBDs’ continue to decline in their relative importance as employment centres and, unfortunately, transit agencies continue to stake their future to a declining travel market, a problem demonstrated by worsening riding habit and service productivity trends in recent years. There is a growing body of evidence, that multi-destination transit systems are far more effective in attracting passengers and more efficient in use of resources to carry each passenger than central business district (CBD)-focused systems (when a significant shift towards decentralisation of centres within a city has occurred) (Thompson et al., 2012).

Figure 31 shows the traditional (radial) network design on the left (and a section of Christchurch’s radial network below) versus the multi-destination transit system design on the right of the figure. Figure 32 shows the new Christchurch Bus Interchange (the blue circle in the centre of the Christchurch network map, corner Lichfield St and Colombo St).

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52 Note that the Christchurch earthquakes and the subsequent loss of the CBD occurred between the 2006 and the 2013 censuses.

Figure 31: traditional (radial) network design versus the multi-destination network design

Adapted from: Thompson, Brown, Bhattacharya, & Jaroszynski (2012) and the Christchurch Metro Network webpage

The multi-destination system structure is designed to focus on a diverse array of possible travel destinations by decentralising the transit network to better fit the decentralised pattern of regional travel destinations (the design’s main strength). Its weakness is that it must rely on passenger transfers to facilitate the various connections, a key difference from the traditional radial structure that emphasises ‘one-seat’ rides whenever possible (although this is commonly not achieved in low density cities). While the transfer is the key to making the multi-destination system work it is also a potential stumbling block if it is not well-coordinated.

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The Christchurch Bus Interchange was designed to provide a first class passenger experience including an integrated wayfinding signage strategy and a practical balance between aesthetics and usability. The Interchange also features space for 100 covered bike racks and the exchange was designed to make it easy for commuters to wheel their bike through the Interchange and find the departing bus platform (access to load the bike rack is provided via a push-button operated sliding adjacent to each bus bay.

**Australian research**

Recent Australian research has focused on modifications and enhancements to existing radial networks. An analysis of over 80 Australian and international schemes was undertaken in an Austroads review project (Austroads, 2000) and the broad analysis of schemes revealed the following patterns of effectiveness:

- The implementation of priority bus ‘super routes’ (SRs) returned patronage increases in the order of 10-15% improvement (for SRs and 30-40% for completely separated bus only links).
- The provision of bus lanes with SR-type priority measures led to 10-15% patronage increases.
- The provision of several high frequency mini-bus services led to 20% patronage growth on individual routes.
- Telematic schemes generated 5% increases in patronage.

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56 SRs take on the following characteristics: minimising delay through measures such as bus lanes, busways, spread stops (skip-stop), priority signalling, high frequency services, the newest vehicles from the fleet, better stop facilities and real time information (but via mixed-traffic routes, not Bus Rapid Transit separated busways).

57 Their effectiveness relates to the physical separation of buses from the other vehicles on the road, thereby allowing buses to avoid congestion, increase average speeds and reduce travel time variation.

58 Off-peak services can result in large, near empty buses travelling around suburban streets. The use of ‘mini’ and ‘midi’ sized buses can be an effective alternative to using full-size buses. They are more cost effective when passenger demand is low. A change to higher frequency of service may be necessary in peak periods to cater for the higher demand.
Bus Rapid Transit (Auckland only)

Bus Rapid Transit (BRT) involves a dedicated busway, for modern, higher capacity buses separated from other traffic as much as possible, along dedicated routes only. Generally, BRT aims to combine the capacity and speed of light rail with the flexibility, lower cost and simplicity of a bus system. Auckland is the only city in New Zealand that currently has a BRT system (therefore BRT is only covered briefly here). Officially opened in February 2008, the Northern Busway is a segregated busway with dedicated park-and-ride facilities along State Highway 1, linking the North Shore with the north end of the Auckland Harbour. To some degree, BRT (and Mass Rapid Transit in general, bus or rail based) can limit ‘diffuse’ sprawl as Mass Transit tends to concentrate urban development in accessibility corridors (only if the provision of transport systems is linked with appropriate land use policies, in a coordinated way. On the other hand, some argue that the increase in average speed of a city’s transport system calls for more space and thus ‘causes’ urban sprawl reduced population density (Lefèvre, 2009).

Bus facilities safety checklist

Public transport infrastructure and traffic management measures that assist public transport can have negative impacts on cycling in many different ways, causing cyclists delays, inconvenience and increased risk of crashes. Proposals that have potential impacts on the convenience or safety of cyclists should be subject to a cycle audit process and to make a cycle audit more specifically appropriate to proposals for bus priority, the additional items listed in Box 5 can be considered (Austroads, 2005, p.45).

Box 5: An example of a specific Cycle Audit checklist

- If a bus lane is proposed, will cyclists be allowed to use it, and if they will, will the bus lane be of sufficient width to accommodate buses and cyclists. If they will not, is there an alternative route that is suitable for cyclists?
- If other forms of bus priority are proposed, what are the impacts on cyclists? Does the bus priority restrict access for cyclists or put cyclists in more vulnerable positions in the roadway?
- Have bus stops and bus shelter locations been designed to allow the safe passage of bicycles past them?
- Where buses are required to turn next to cyclists, does swept path of the buses encroach upon the cyclist’s road space?
- If ‘B’ bus priority lights are proposed, has consideration been given to the needs of cyclists?


Practical Tool

Box 5: An example of a specific Cycle Audit checklist

- Electronic passenger information systems that transfer information to both users (real time information on arrival times, delays) and operators (driver information, vehicle locations).
- BRT provides separated lanes whereas Bus Priority (BP) only involves peak period bus lanes and priority traffic signals for buses, along mixed traffic routes.
Economics

The scope of this report does not include a stand-alone search, review and synthesis of published economic analyses and/or evaluations, and no attempt has been made to compare and contrast the relative cost-effectiveness of individual items of infrastructure (for example comparing the relative merits of a cycle path vs a cycle lane in dollar terms). However the following overview is provided to outline the general principals and to overview the nature of the evidence base. Several references are provided within the text to guide further reading.

Economic appraisal (cost-benefit analysis) is an established practice in transport planning, however, the full health effects of transport interventions are rarely taken into account. In part, this is because the methodology for evaluating active and public transport infrastructure projects across the full range of outcomes is not well developed or standardised (especially with regard to health) (Kahlmeier, Racioppi, Cavill, Rutter, & Oja, 2010). Most tools for evaluating the economic value of transport policies and projects have tended to be specific to evaluating a single mode or objective (Litman, 2015). For example, highway investment models are designed to measure the value of road improvements, and emission reduction models are designed to prioritise emission reduction strategies. These narrowly scoped “reductionist” models are poor at evaluating multiple modes and objectives and they may point to solutions to one problem that exacerbate others, as well as undervaluing strategies that provide modest but multiple benefits, such as public transport services (NZTA, 2010).

The potential benefits derived from active and public transport include (but are not limited to): improved travel times; more flexible mode choices; impacts on air quality, greenhouse gases, and noise; physical activity variables; quality of life; mortality; and the wider direct and indirect economic impacts, including impacts on local business and retail establishments; and land use. While these diverse factors make measurement and evaluation challenging, they all need to be considered in order to estimate the full value of a particular infrastructure intervention (Cavill, Kahlmeier, Rutter, Racioppi, & Oja, 2008).

Nevertheless, even when using conservative assumptions and methods, investment in cycling-specific infrastructure has consistently been shown to have positive results, generally because the value of health benefits (over time) can be substantial and far exceed the initial construction costs (Daley, Rissel, & Lloyd, 2007; Garrard, Rose, & Lo, 2008; Pucher et al., 2010; Sloman, Cavill, Cope, Muller, & Kennedy, 2009). Results show that substantial health-related cost savings can be expected from promoting active transport. Typically, the benefit-to-cost ratio of building cycle networks is reported to range between approximately 1.5:1 and 4:1 (in other words, returning between $1.50 and $4.00 for every dollar spent) (AECOM, 2010; Lee & March, 2010; PriceWaterhouseCoopers, 2009). By comparison, typical benefit cost comparisons for other kinds of large scale transport investment are much less favourable. For example, the Roads of National Significance have been variously reported as having benefit to cost ratios of 0.1 to 561 (in other words, returning between 10c and $5 for every dollar spent)(Macmillan et al., 2014).

61 Estimates vary depending on the road/scenario, the scope of the summed net benefits and costs, the analytical methods used, and other assumptions.
In New Zealand, a Transport Authority report (Genter et al., 2008) used the ‘HEAT’ for cycling appraisal tool (Rutter et al., 2008) to calculate an average annual value of a person being active of about NZD2,500 to NZD3,300 including mortality and morbidity. The HEAT for cycling tool was also used to estimate health cost savings in urban adults associated with modal shift to cycling (on short urban trips). In economic terms, including only fatalities, the health effects of a 5% shift towards active transport represent net savings of about $200 million per year (Lindsay, Macmillan, & Woodward, 2011). Lindsay et al. (2011) concluded that the health benefits of moving from cars to bikes heavily outweigh the costs of injury from road crashes. Further, in the most recent New Zealand study, Macmillan et al. (2014) undertook a comprehensive assessment of future costs and benefits to society of specific active transport policies in Auckland. They concluded that high quality (public and active transport friendly) changes to main roads and local streets across the region are potentially extremely cost effective, accruing more than $20 in benefit to society for every dollar spent over the next 40 years (a 20:1 benefit to cost ratio).

In more recent years the “Health in All Policies” approach (Council of the European Union, 2006) has emerged as a means to promote and protect health through transport policy decisions, taken outside the health sector, but informed by economic analyses that include the economic savings from the health effects of active travel. Economic evaluations can therefore be useful when identifying win-win situations that allow the target sectors to achieve their own goals while at the same time protecting and promoting health.

Placing health benefits into economic terms can support a powerful argument for active transport infrastructure, using a “Health in All Policies” approach (United Nations Economic Commission for Europe & WHO Regional Office for Europe, 2009). Including economic savings from the health effects of active travel into standard economic assessments of transport interventions is essential to make these potential co-benefits explicit (Kahlmeier et al., 2010). However, there is a need for a more methodologically consistent approach to the evaluation of health benefits from cycling and walking.

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62 Health in All Policies is an approach that considers the health impacts of policy across all sectors, with the aim of achieving health gains while also enhancing the non-health interests and intentions of the various sectors or agencies involved.
Conclusions

Based on the literature reviewed, there is no doubt that infrastructure interventions that increase walking and cycling, with public transport for longer journeys, could result in major public health benefit and have a substantial role in meeting targets for greenhouse gas emissions. Specifically, commuter behaviour (mode choice) is heavily influenced by the type and quality of infrastructure that the user encounters on a trip-by-trip basis. From a public health perspective, equity is also an important element of quality, and active transport infrastructure (and the planned distribution of that infrastructure across a city network) needs to be ‘pro-equity’ — that is, be readily accessible to all, especially those who are least advantaged.

When formulating a cohesive plan or proposal, there are many inter-related variables that need to be considered including (but not limited to): economics, aesthetics, environmental sustainability, fuel efficiency, quality, service and satisfaction, capacity, travel time, social aspects, impacts of urban form, and health. The examples and evidence presented in this report are principally viewed through a public health lens and, inevitably, most of these transport-related variables act as direct or indirect determinants of health. The transport planning/outcome variable ‘Level Of Service’ is an important measure because level of service refers to the perceived quality of the transport experience, which includes safety, and, overall, level of service is strongly related to the likelihood that a person will use a particular mode of commuting (a higher mode-specific level of service generally makes it more likely that people will use that particular transport mode). Active and public transport level of service is heavily influenced by the quality of infrastructure interventions. For example, fully separated cycle paths consistently provide higher level of service than painted cycle lanes, because (among other things) they are experienced as safe by cyclists (and cyclists or potential cyclists value safety greatly). Level of service can be viewed as a proxy measure for a number of relevant public health objectives, these include (but are not limited to): reducing injury, the promotion of physical activity, improved wellbeing, and enhanced environmental sustainability.

Christchurch City (and the Greater Christchurch area) is simultaneously ‘recovering’ and ‘regenerating’ from the Canterbury Earthquakes as well as evolving on a natural trajectory — underpinned by the types of demographic shifts and global influences (including age, economic and social) that are shaping urban form in many modern cities (e.g. urban sprawl — a ‘flatter’ population density gradient, and increased levels of transport energy expenditure).

At the practical/operational level, repair of existing infrastructure and reinstating (at least) pre-earthquake levels of service for active and public transport users in Christchurch would appear to be essential if public transport and active transport mode share is to be maintained/increased. A large body of research confirms that cyclists are particularly sensitive to road surface conditions and increased smooth travel exposure favourably impacts travel time, enjoyment and safety for cyclists and may significantly influence cycling rates independently of built infrastructure initiatives. In the specific case of Christchurch, particularly in the East, the nominal smoothness of much of the cycling road surface has been significantly reduced post-earthquakes; by differential subsidence, patching, mechanical damage, incomplete seal to shoulders, liquefaction, raised/sunken inspection covers/sewer vents and gulley traps, and other deformities (in addition to damaged guard rails and overhanging trees and other objects due to lack of maintenance or repairs). The Christchurch City
Council estimates that it may take up to 30 years to repair all of the damage (a ‘local smoothing programme’ may alleviate the most dangerous faults in a shorter time frame).

Beyond recovery and repair, selecting the appropriate type, level and quality of new public and active transport infrastructure is always likely to involve stakeholders debating multiple competing issues. These issues may include considerations around transport and community, transport and environmental objectives, as well as technical, financial, safety and organisational factors. However, transport decisions are also, at least in part, ideological in nature, and they represent differing views of the proper distribution of costs and benefits across stakeholder groups (e.g. business owners, home owners, school children, the employed, the unemployed, environmentalists). Key themes in transport infrastructure planning debates often reflect differing views on transport projects versus other community objectives and differing views on the relative merits of investing in private versus public modes.

The traditional car-centric type of planning ideology has led to a massive expansion in road capacity over the last few decades, which has led to a phenomenal growth in car use in the suburbs. Increasingly, traffic congestion threatens the ‘ideal’ that motor vehicle users can enjoy both fast access across and out of town, and a quiet neighbourhood in which to live. Increasingly, traffic congestion is forcing a rethinking of much of what transport planners have done previously. Contemporary traffic planning is now giving greater consideration to the ‘link’ and ‘place’ functions of streets and the impact of road and network design on the ‘liveability’ of streets, quality of life, and the enabling of sustainable transport choices.
References


Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: an international review Preventive Medicine, 50(Suppl. 1), S106–125.


Appendix A: Methods

The review question was defined according to the population, intervention, comparator, outcomes, and time (PICOT) criteria, and the types of studies, as detailed below (Table 10). These criteria were developed *a priori*.

Table 10: Criteria for determining study eligibility

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<tr>
<th>PICOT</th>
<th>Inclusion criteria description</th>
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<tr>
<td>Participants/population</td>
<td>All adults [excluding car drivers] (with or without disability/mobility impairment) and children (supervised and unsupervised) who traverse or otherwise use [for transport], Christchurch’s public road network (including footpaths and shared spaces). Such use by ‘commuters’ may include trips of one or more of the following five common journey purposes: commuting to work, travel for education, travel in the course of business, shopping or personal business, and social or leisure activities. The scope is limited to the following transport modes: walking and cycling including the use of adapted cycles (such as trikes, tandems and handcycles), wheelchairs and similar mobility aids (does not specifically include skateboards, scooters, rollerblades and similar modes, but does not exclude these modes).</td>
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| Intervention* | Environmental-level interventions (infrastructure) that reduce the exposure of the population of interest to moving vehicles (i.e. concerned with the safety of active transport commuters not car drivers).  
*Active transport infrastructure may include:*  
- Re-allocating road space to support physically active modes of transport (e.g. introducing cycle lanes)  
- Restrict motor vehicle access [capacity] (e.g. by narrowing roads to reduce capacity)  
- Creating safe routes to schools (e.g. by using traffic-calming measures near schools and by creating or improving walking and cycle routes to schools.... where these involve the installation of new infrastructure).  
- Introducing traffic-calming schemes to restrict vehicle speeds (e.g. horizontal and/or vertical infrastructure) including—*horizontal*: widening the pavement, pavement buildouts at intersections or in mid-section, chicanes and central refuges, advanced stop boxes, intermittent parking, sculptures or plantings and—*vertical*: speed humps, speed tables and speed cushions.  
- Separated walking/bicycle facilities  
- End-of-trip facilities (including stands, covered stands/storage/interchanges)  
- Displacement of vehicle parking (an auto end-or-trip facility)  
- Signs and signals  

AND

The necessary/typical/desirable transit infrastructure (bus only) that is/should be considered ‘alongside’ active transport infrastructure: because, (A) transit infrastructure must co-exist with active transport infrastructure in some contexts, and may interact with (possibly negatively) the provision of best practice active transport infrastructure and (B) because the level of transit infrastructure (or lack thereof) influences modal share (patronage) and therefore has direct and indirect public health relevance.  
*Transit infrastructure may include:*  
- Bus interchanges (central/main)  
- Suburban interchanges (key activity centres)  
- Bus stops (including distance between)  
- Bus lanes  
- Signals and signs |
| Comparator | No intervention. No implementation of [safety] infrastructure. Poor implementation. |
| Outcomes | Primary outcome: Level of Service (LOS) specific to each transport mode (walking, cycling, bus). Walking/cycling LOS is heavily influenced by bicyclists’ perspective of the safety of sharing the roadway environment with motor vehicle traffic. Public transport (bus) LOS is mostly influenced by variables relating to efficiency/speed. Secondary outcomes may include: vehicle speeds, traffic volumes by mode. Cost-effectiveness/cost-benefit ratios will only be reported in cases where this information is explicitly provided by report authors. |
| Time | Long-term effects (sustainable/lasting), service life |
### PICOT

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<th>Exclusion criteria description</th>
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<tr>
<td><strong>Excluded participants/population</strong> Users/drivers of motorised vehicles (does not exclude mobility scooters specifically) on Christchurch’s public road network (including footpaths and shared spaces). Note: while transit infrastructure will be included in the review for the reasons ‘A’ &amp; ‘B’ listed above (and reported in the define/describe/illustrate/ high-level guidance format previously described), the review will not include a [fully] detailed analysis of transit user's LOS, because a number of transit LOS variables are under the discretion of the transit operator [vs the roadway owner] i.e. transit operator variables such as headway factor, reliability, quality of vehicles, number of seats and level of comfort/service provided in interchanges therefore, they are [at least in part] policy/operational in nature, rather than infrastructure. A full analysis of transit LOS is beyond the scope of this review.</td>
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| Excluded intervention types Legislative interventions, media and social marketing campaigns, cycling skills training or other education programmes. Excludes the planning and provision of a whole network of routes for walking, cycling and the use of other modes of transport that involving physical activity although these might be desirable, “planning” as such is outside the scope of this proposed review and only specific examples of infrastructure/installation are included within the scope). Excludes interventions such as school travel plans although these might be desirable where these do not involve the installation of new infrastructure to improve safety. |

| Outcomes not covered by this review LOS (by auto/transit mode), auto/transit safety, vehicle speeds, traffic volumes by auto/transit mode (where these do not inform active transport safety) |

| Time Novelty effects, halo effects, short-term transient changes in outcomes that revert to baseline |

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1 Notes: It is difficult to compare contexts and settings exactly but evidence/examples will be selected on the basis that they reflect typical New Zealand setting as much as possible. While the review will identify the infrastructure types typically associated with effectiveness, the simple inclusion of these infrastructure elements in a specific situation may not adequately describe or predict overall effectiveness (of the road(s) design). The review will consider implications for Māori and report Māori-specific research findings where available [at the risk of pre-empting findings, it is unlikely that any information will relate specifically to Māori or any other specific population groups]. It is unlikely that evidence-based comment will be included on issues of equity [although there is a body of research on this topic].

**Types of evidence**

The types of studies considered as eligible were secondary research: including guidelines, reviews, economic analyses and meta-analyses as well as selected English-language journal articles appearing in the published academic literature. Study types not eligible for this review include, individual randomised controlled trials (RCT) and other experimental and quasi-experimental studies (two exceptions were for literature specifically related to transport infrastructure interventions conducted in New Zealand, and studies investigating important system-dynamics or the interaction of transport infrastructure and human behaviour (because some assumptions need to be evidence based at a fundamental level).

**Literature search**

A systematic method of literature searching and selection was employed in the preparation of this review. Searches were limited to English-language peer-reviewed review material published from 2010 onwards. This publication year range provides for an up-to-date evidence base that seeks to capture current best practice and any emerging traffic management technologies.63

The following databases were searched:

a) Austroads Publications Online,64
b) New Zealand Transport Agency,

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63 Some studies of certain fundamental principles are drawn from a wider year range.

64 A database of evidence-based design guides and more than 600 technical and research reports, applicable to Australia and New Zealand.
c) bibliographic databases including PubMed, PsycINFO, and
d) government transport agency websites.

Search terms were used as keywords, expanded where possible, and as free text within the title
and/or abstract fields. Key words/search terms included: active transport, transit, cycling, bicycling,
walking, bus, safety, infrastructure, transportation, cost-effectiveness, and transport planning.

A search was also conducted specifically for reviews and individual transport infrastructure
interventions and case-studies undertaken in Aotearoa New Zealand.

A broad search was also conducted using Google Scholar and nzresearch.org.nz using various
combinations of the search terms listed above. The reference lists of included publications were also
scanned to identify any additional (and relevant) publications. Grey literature and unpublished
material such as conference abstracts were not included in this report.

Assessment of study eligibility
Broadly, reports, guidelines and studies were selected for inclusion in the review using a two-stage
process. First, the titles (and/or) abstracts identified from the search were scanned and exclusions
were made as appropriate. Second, the full-text articles and guidelines were retrieved (where
possible) for the remaining publications, and these were selected for inclusion in the review if they
fulfilled the study selection criteria. EndNoteX7™ was used to manage citations (Thomson Reuters,
1988-2015©) with user-defined custom fields to tag all citations over the two appraisal passes
(title/abstract and full-text). Internal searches were used to generate the final included study list.

Data synthesis
This review takes an integrative review approach to information synthesis. This integrative review is
structured to allow for the inclusion and summary of a range of publication types ranging from single
research studies or case studies to comprehensive design guidelines. This review aims to capture the
context and application on specific infrastructure elements and their likely (or known) effects on
road-user LOS.

Limitations of this review
The literature search was restricted to English language publications. Also, no attempt was made to
identify unpublished studies. This review is necessarily limited in scope and excludes non-
infrastructure interventions and programmes. It should also be noted that the local environment
(specific New Zealand context) in which interventions are implemented is likely to influence
effectiveness. Attitudes and cultural norms about active transport may influence outcomes,
compared to other countries from which examples may be sourced. In addition, only the safety-
related and LOS outcomes of interventions were considered in this review. However it is
acknowledged that there are many non-safety related outcomes that might be of interest to
different groups (e.g. businesses).

65 http://nzresearch.org.nz/
## Appendix B: Key policies and innovations

Key policies and innovative measures used in Dutch, Danish and German cities to promote safe and convenient cycling

<table>
<thead>
<tr>
<th>Extensive systems of separate cycling facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Well-maintained, fully integrated paths, lanes and special bicycle streets in cities and surrounding regions</td>
</tr>
<tr>
<td>- Fully coordinated system of colour-coded directional signs for bicyclists</td>
</tr>
<tr>
<td>- Off-street short-cuts, such as mid-block connections and passages through dead-ends for cars</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intersection modifications and priority traffic signals</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Advance green lights for cyclists at most intersections</td>
</tr>
<tr>
<td>- Advanced cyclist waiting positions (ahead of cars) fed by special bike lanes facilitate safer and quicker crossings and turns</td>
</tr>
<tr>
<td>- Cyclist short-cuts to make right-hand turns before intersections and exemption from red traffic signals at T-intersections, thus increasing cyclist speed and safety</td>
</tr>
<tr>
<td>- Bike paths turn into brightly coloured bike lanes when crossing intersections</td>
</tr>
<tr>
<td>- Traffic signals are synchronized at cyclist speeds assuring consecutive green lights for cyclists (green wave)</td>
</tr>
<tr>
<td>- Bollards with flashing lights along bike routes signal cyclists the right speed to reach the next intersection at a green light</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traffic calming</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Traffic calming of all residential neighbourhoods via speed limit (30 km/hr) and physical infrastructure deterrents for cars</td>
</tr>
<tr>
<td>- Bicycle streets, narrow roads where bikes have absolute priority over cars</td>
</tr>
<tr>
<td>- ‘Home Zones’ with 7 km/hr speed limit, where cars must yield to pedestrians and cyclists using the road</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bike parking</th>
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</thead>
<tbody>
<tr>
<td>- Large supply of good bike parking throughout the city</td>
</tr>
<tr>
<td>- Improved lighting and security of bike parking facilities often featuring guards, video-surveillance and priority parking for women</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coordination with public transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Extensive bike parking at all metro, suburban and regional train stations</td>
</tr>
<tr>
<td>- ‘Call a Bike’ programmes: bikes can be rented by cell phone at transit stops, paid for by the minute and left at any busy intersection in the city</td>
</tr>
<tr>
<td>- Bike rentals at most train stations</td>
</tr>
<tr>
<td>- Deluxe bike parking garages at some train stations, with video-surveillance, special lighting, music, repair services and bike rentals</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traffic education and training</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Comprehensive cycling training courses for virtually all school children with test by traffic police</td>
</tr>
<tr>
<td>- Special cycling training test tracks for children</td>
</tr>
<tr>
<td>- Stringent training of motorists to respect pedestrians and cyclists and avoid hitting them</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traffic laws</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Special legal protection for children and elderly cyclists</td>
</tr>
<tr>
<td>- Motorists assumed by law to be responsible for almost all crashes with cyclists</td>
</tr>
<tr>
<td>- Strict enforcement of cyclist rights by police and courts</td>
</tr>
</tbody>
</table>

*From: (Pucher, 2001)*
Appendix C: The One Network Road Classification system

Figure 33: The One Network Road Classification system graphic


The ten variables that determine road classification are:

- Typical daily traffic
- Heavy commercial vehicles (daily vehicle flows)
- Buses (buses/passengers per hour)
- Active modes (significant numbers of pedestrians and cyclists or part of identified cycling or walking network)
- Linking places (centres of population)
- Critical connectivity (remote regions/sole connectivity)
- Freight
- Airport passenger numbers
- Significant tourism destinations and significant scenic routes
- Access to hospitals
Appendix D: The Urban Cycleways Programme
The Christchurch City Council is building a network of 13 Major Cycle Routes. They will link suburbs, education facilities, business and shopping areas as well as popular recreational destinations. They will “offer a level of service not seen before in Christchurch, and enable younger and less confident riders to feel safe and increase the number of cycle trips they take” (www.ccc.govt.nz/cycleways).

Figure 34: Priority Cycleway Projects, April 2013, Christchurch, showing completed projects in orange and those proposed for 5-year delivery in red.

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The Urban Cycleways Programme is made up of shared investment from the Urban Cycleways Fund (Government), the National Land Transport Fund (NZ Transport Agency) and local councils. This enables key, high-value urban cycling projects to get underway around the country over the next three years, improving cycle safety and supporting more connected cycle networks.
Appendix E: Collection of practical tools and checklists

This appendix includes the ten practical tools (tables, figures, checklists and notes) that are included within this document. Each tool is duplicated here and a cross-reference link is provided to assist navigation to the relevant section in the main body of the document.

**Practical Tool (1)** is a summary from Thomas and DeRobertis (2013) of the most effective intersection treatments with an estimation of the probable gains in safety attributable to each. For more information and to see this table in context, click on the following link: [Basic principles in active transport infrastructure design](#)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Gains in safety</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parallel treatments (convert path to lane)</strong></td>
<td></td>
</tr>
<tr>
<td>– Bringing the cycle track closer to the parallel auto traffic at the intersection approach to increase the visibility of cyclists to motorists (e.g. convert cycle path to cycle lane 20–30 m in advance of intersection†).</td>
<td>31% - 51%</td>
</tr>
<tr>
<td>– Bring together but maintain physical separation, also with the use of advance stop line for motorists 3–5 m behind waiting cyclists.</td>
<td></td>
</tr>
<tr>
<td><strong>Raised cycle crossings</strong></td>
<td>33%</td>
</tr>
<tr>
<td>– Raising cycle crossings to the level of the cycle path, essentially providing a speed hump, to lower vehicle turning speeds and reduce injuries to cyclists.</td>
<td></td>
</tr>
<tr>
<td><strong>High-visibility painted surfaces</strong></td>
<td>10-19%</td>
</tr>
<tr>
<td>– Coloured cycle crossings (green) through intersections (less effective if overused).</td>
<td></td>
</tr>
<tr>
<td>– Bicycle stencil in advance of intersection on cross-street approach.</td>
<td></td>
</tr>
<tr>
<td><strong>Signals</strong></td>
<td>High‡</td>
</tr>
<tr>
<td>– Providing dedicated cyclist signals to separate the cyclist through-movement from turning vehicles.</td>
<td></td>
</tr>
</tbody>
</table>

*No attempt was made to quantify the effects of combining a number of intervention elements.
† This solution is reportedly unpopular among cyclists because it makes them feel less safe, however the evidence suggests objectively measured safety is increased.
‡ This has generally not been quantified formally, probably because prioritised signals are already known to provide a temporal separation between motorists and cyclists.

**Source:** summarised from Thomas & DeRobertis (2013)
Practical Tool (2) is a four-stage approach to appraising infrastructure proposals. This balanced approach to street planning and design can be applied in the case of lightly-trafficked residential roads as well as busier streets (for example these principles have now been incorporated in the Manual for Streets 2 (CIHT, 2010) and illustrated in several case studies in Australia and the UK (Jones & Boujenko, 2011) (CIHT 2010). For more information and to see this checklist in context, click on the following link: Using the Link-Place framework as an appraisal tool

i. Identify the relevant Link and Place performance indicators that reflect the potential range of street users and street problems (these might include indicators of transport performance, safety, economic vitality and environmental quality).

ii. Identify the (potential) ‘degree of problem’ (if any) for each indicator (i.e., if considering safety, how far away is the proposal from delivering a minimum acceptable level of safety?). This can be assessed on an agreed rating scale, such as from 0 (no problem) to 10 (severe problem).

iii. Consider which function (Link or Place) has the higher priority (consider the relative weightings based on the Link/Place categories for each road segment – as expressed by stakeholders).

iv. Recommend/implement changes to the proposal if required: recognising that the link requirements have to be balanced against a wide range of other place-related needs that may have equal legitimacy. In practice, the optimal design solutions may vary along a corridor, even if the link status remains the same throughout, due to the varying importance and nature of place user needs, and differences in the available street width, from one road segment to the next.

Adapted from: Jones & Boujenko (2011)
To estimate the variables required by the LOS models, the analyst first collects data on the geometric cross-section of the street, signal timing, the posted speed limit, bus headways, traffic volumes, transit patronage, and pedestrian volumes and facility maintenance.

The analyst uses these data to estimate various modal performance characteristics (auto speed, bus speed, bus wait, and bus access, bicycle-pedestrian conflicts if a shared facility is present, and pedestrian density).

Once the modal performance characteristics are known, then the auto LOS, transit LOS, bicycle LOS, and pedestrian LOS for the urban street can be calculated (and converted to a six-letter grade A-F).

The bicycle-pedestrian conflict LOS can also be estimated.

The multi-modal LOS method enables agencies to test (model) and optimise different allocations of scarce street right-of-way to the different modes using the street (evaluating the ‘trade-offs’) (Dowling, 2009; NCHRP, 2008).

MMLOS can also be applied to describe major signalised intersections as a road segment.

Notes
– An ‘A’ grade for Auto LOS is generally unrealistic in urban areas. Urban areas more typically adopt standards varying between C and E, depending on the area’s size and characteristics, while F might be allowable in areas with improved pedestrian, bicycle, or transit alternatives.
– MMLOS planning and design must take into account additional factors like capacity utilisation, accessibility, safety, cost-effectiveness, the effect on the environment, and each agency’s goals and objectives.
– The various modes interact with each other such that improvements in the quality of service for one mode may improve or lower the quality of service for another mode.
– The NCHRP’s modelling system only incorporates safety and economic aspects insofar as they influence road users’ perceptions of LOS (i.e. safety and economic aspects are not explicitly included or excluded from the LOS models) (NCHRP, 2008). These multi-modal LOS methods can involve complex statistical modelling, however the basic appraisal framework might still be useful for identifying and evaluating any apparent ‘trade-offs’ on a more subjective basis.

Practical Tool (3) overview of multi-modal LOS methods.

– To estimate the variables required by the LOS models, the analyst first collects data on the geometric cross-section of the street, signal timing, the posted speed limit, bus headways, traffic volumes, transit patronage, and pedestrian volumes and facility maintenance.
– The analyst uses these data to estimate various modal performance characteristics (auto speed, bus speed, bus wait, and bus access, bicycle-pedestrian conflicts if a shared facility is present, and pedestrian density).
– Once the modal performance characteristics are known, then the auto LOS, transit LOS, bicycle LOS, and pedestrian LOS for the urban street can be calculated (and converted to a six-letter grade A-F).
– The bicycle-pedestrian conflict LOS can also be estimated.
– The multi-modal LOS method enables agencies to test (model) and optimise different allocations of scarce street right-of-way to the different modes using the street (evaluating the ‘trade-offs’) (Dowling, 2009; NCHRP, 2008).
– MMLOS can also be applied to describe major signalised intersections as a road segment.

Notes
– An ‘A’ grade for Auto LOS is generally unrealistic in urban areas. Urban areas more typically adopt standards varying between C and E, depending on the area’s size and characteristics, while F might be allowable in areas with improved pedestrian, bicycle, or transit alternatives.
– MMLOS planning and design must take into account additional factors like capacity utilisation, accessibility, safety, cost-effectiveness, the effect on the environment, and each agency’s goals and objectives.
– The various modes interact with each other such that improvements in the quality of service for one mode may improve or lower the quality of service for another mode.
– The NCHRP’s modelling system only incorporates safety and economic aspects insofar as they influence road users’ perceptions of LOS (i.e. safety and economic aspects are not explicitly included or excluded from the LOS models) (NCHRP, 2008). These multi-modal LOS methods can involve complex statistical modelling, however the basic appraisal framework might still be useful for identifying and evaluating any apparent ‘trade-offs’ on a more subjective basis.

Practical Tool (4) The 37 NCHRP modelling system variables. The NCHRP’s modelling system relies on 37 variables to predict the perceived degree of satisfaction experienced by travellers on the urban street.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Auto (car)</th>
<th>Bus</th>
<th>Cycle</th>
<th>Pedestrian</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS inputs</td>
<td>Stopped or delayed</td>
<td>Pedestrian LOS*</td>
<td>Bike-Pedestrian conflicts*</td>
<td>Pedestrian density</td>
</tr>
<tr>
<td>variables</td>
<td>Right turn lane</td>
<td>Bus headway</td>
<td>Driveway conflicts/Km</td>
<td>Pedestrian-Bike conflicts*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bus speed</td>
<td>Vehicles per hour</td>
<td>Width of shoulder</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bus schedule adherence</td>
<td>Vehicle through lanes</td>
<td>On-street parking occupancy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passenger load</td>
<td>Auto speed</td>
<td>Presence of trees</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bus stop amenities</td>
<td>Percent heavy vehicles</td>
<td>Footpath width</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pavement condition</td>
<td>Distance to travel lane</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Width of outside lane</td>
<td>Vehicles per hour</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>On-street parking occupancy</td>
<td>Vehicle through lanes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Side road width</td>
<td>Average vehicle speed</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Left turns on red</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Side street speed</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Side street vehicles/hour</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Side street lanes</td>
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<td></td>
<td></td>
<td>Crossing delay</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Left-Turn channelisation</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Block length</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Signal cycle length</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Signal green time</td>
</tr>
</tbody>
</table>

*Because transitioning to transit modes almost always involves a pedestrian segment.
+Pedestrian/bike conflicts come into play only for paths outside of roadway but within right-of-way of street.
**Practical Tool (5)** is the most commonly used quick-guide chart for the selection of an appropriate type of bicycle facility. The figure illustrates the degree of separation required for cyclists as a function of the speed and volume of the general traffic flow. This figure has been widely reproduced and can be found in many national design guidelines. However the figure is based on only a small number of relatively old studies (specifically, Centre for Research and Contract Standardization in Civil and Traffic Engineering (CROW), 1993; DELG, 1999; Ove Arup and Partners 1997; RTA, 2003). Subsequently, a number of caveats and notes have been added to the chart in successive publications (e.g., Austroads, 2014a) and these should be considered and weighted alongside the basic thresholds shown on the chart —

1. Experienced road cyclists are unlikely to use off-road facilities with low design speeds, even on routes where the road carries high volume, high speed traffic. On-road bicycle lanes or suitable road shoulders may still be required in addition to off-road facilities.

2. In general, roads with higher traffic speed and traffic volumes are more difficult for cyclists to negotiate than roads with lower speeds and volumes. The threshold for comfort and safety for cyclists is a function of both traffic speed and volume, and varies by cyclist experience and trip purpose. Facilities based on this chart will have the broadest appeal.

3. When school cyclists are numerous or the route is primarily used for recreation, path treatments may be preferable to road treatments (also path widths need to be wide enough to accommodate school cyclists in particular, as school cyclists tend to be numerous and clustered).

4. Provision of a separated cycle path does not necessarily imply that an on-road solution would not also be useful, and vice versa.

5. Different kinds of cyclists have different needs. Family groups may prefer off-road cycle paths while racing or training cyclists, or commuters, tend to prefer cycle lanes or wide sealed shoulders. For more information and to see this content in context, click on the following link: [Type of bicycle facility required: mixed-traffic, lane or path?](#)
Practical Tool (6) lists and describes a number of the most common mid-block facility types that aim to improve cycling and pedestrian level-of-service and safety. The advantages and disadvantages of selected infrastructure types are listed, and for cycling, the infrastructure elements are rated for suitability for novice cyclists including children and for experienced/commuter cyclists using a 5-star rating. The table is based on existing guides and design manuals, New Zealand legislation and the collective opinions of a range of cycling and pedestrian facility planners and commentators (the table does not comprise a full design guide, however further information is available in the cited literature). For more information and to see this content in context, click on the following link:

Midblock facilities for cyclists and pedestrians.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition of mid-block facility types for cyclists and pedestrians</th>
</tr>
</thead>
</table>
| Cycle lane (Kerbside) | Suitability for Child/Novice cyclist = ★★ ★★★★★ | Suitability for Experienced cyclist = ★★★★★

Subcategories of cycle lanes include buffered cycle lanes and contra-flow cycle lanes. Cycle lanes may be adjacent to the kerb (“kerb-side”), adjacent to motor vehicle parking (“car-side”), or between general traffic lanes on the approach to intersections. The delineation is typically achieved by use of pavement markings, with cycle symbols and lane lines as a minimum and coloured surfacing optional. Cycle lanes next to parallel parking should be of the following minimum widths: speed limit or 85th percentile speed 50 km/h = minimum cycle lane width 1.8m and 70 km/h = minimum width 2.2 m (Austroads, 2014a).

- Advantages: All road users are likely to recognise the cycle lane and expect to find cyclists there. It provides a degree of separation between motor traffic and cyclists. Reported injury rate reductions for cycle lanes of between 9% and 50%.
- Disadvantages: This facility restricts car parking. It may not provide enough protection for inexperienced cyclists.
- Summary: As long as car parking issues can be resolved, kerbside cycle lanes are the favoured facility for roads.

| Cycle lane (Car-side) | Suitability for Child/Novice cyclist = ★ | Suitability for Experienced cyclist = ★★★★★

- Advantages: Eliminates the need for parking restrictions and improves the channelling of traffic, encouraging a more orderly and predictable traffic flow.
- Disadvantages: A significant carriageway width is required. Exposes cyclists to the collision risk with car doors.
- Summary: If the road is wide and parking restrictions are unlikely to be acceptable, a cycle lane next to parking is likely to be an appropriate choice. Kerbs protruding the width of the parking bay should be constructed at intervals to discourage vehicles travelling over unoccupied parking spaces.

| Cycle lane (Contra-flow) | Suitability for Child/Novice cyclist = ★ | Suitability for Experienced cyclist = ★★★★★

- Advantages: Contra-flow lanes contribute to the network’s directness and coherence by allowing cyclists to avoid diversions along indirect or less safe routes.
- Disadvantages: Other road users, including pedestrians, may not expect cyclists to travel in the opposite direction to other traffic. Contra-flow lanes generally preclude parking on the cyclist’s side of the road.
- Summary: Contra-flow cycle lanes can be used in one-way streets where cyclists might otherwise be forced to divert along indirect or less safe routes. Intersection layouts must support this facility, particularly at start and end points and at side road intersections.

| Enhanced cycle lane | Suitability for Child/Novice cyclist = ★★ | Suitability for Experienced cyclist = ★★★★★+

Cycle lanes may be enhanced by individual measures such as traffic islands and physical separation at bus stops and other special treatments at side roads, if separated bicycle facilities are not possible.

| Buffered cycle lane |

The buffer is usually created by hatched markings but may also be formed by textured surfaces such as flush pavers or flush printed asphalt. Kerb-side buffered cycle lanes are permissible, however consideration should be given to using the buffer space for stronger separation elements such as bollards, kerbs or flags whereupon the buffered cycle lane becomes a protected cycle lane.

67Motor traffic volume, speed and in some cases the age profile of cyclists using the route can and should influence the choice between a cycle lane, cycle path or mixed traffic solution. Principles for a high standard of intersection design are crucial and should have top priority.
**Protected cycle lane**  
Suitability for Child/Novice cyclist = ★★  
Suitability for Experienced cyclist = ★★★★★  
SBF

Also known as a “separated bicycle lane”, a protected cycle lane is not accessible to cars (except to cross for driveway access). The protection may be provided via raised kerbs, flags, bollards, landscape planters, or other vertical elements. Consideration should be given to the durability of vertical elements employed. One-way and two-way protected cycle lanes are possible (although two-way protected cycle lanes introduce additional complexities at intersections). Protected cycle lanes can offer a low-stress environment that can be attractive to many cyclists. In comparison to a shared path, a two-way protected cycle lane is further from the nearest property boundary and therefore offers better intervisibility between cyclists and motor vehicle drivers exiting a driveway (Figure 16 & Figure 17).

**Cycle path**  
Suitability for Child/Novice cyclist = ★★★★★  
Suitability for Experienced cyclist = ★★★  
SBF

An off-street path can be an exclusive cycle path, a shared use path or a separated path. (LTSA 2004) A cycle path may be within the road reserve, in a park, alongside a river, lake or railway line (NZTA 2008) although typically if not in a road corridor it will be termed a shared path. They may be marked and/or signposted for one-way or two-way cycling. Legally a cycle path may also be used by pedestrians and includes a cycle track formed under section 332 of the Local Government Act 1974…. even if not specifically designated as a shared path.

- Advantages: Separated paths may help to avoid the conflict between pedestrians and cyclists that is common on shared paths. Cyclists can ride without the delays possible on paths shared with walkers.
- Disadvantages: Under New Zealand traffic law, cyclists on paths are required to give way to other traffic when crossing side roads. This results in delay for cyclists. Separated paths are wider than other paths, so they cost more. Higher cyclist speeds are possible and separated paths require special intersection treatments to ensure that high speeds are controlled at intersections and that cyclists can merge safely. It is less convenient to turn right from a protected cycle lane next to a road. Cyclists have to cross the whole traffic stream in one manoeuvre, whereas from a cycle lane they can first merge across to the centre. However, a right turn from a separate path may be safer.
- Summary: Separated paths are appropriate if large numbers of cyclists will use them. There should be adequate separation (such as different path levels) between cyclists and pedestrians. Between intersections, cycle paths next to roads can provide attractive and safe facilities for a wide range of cyclists, provided there is adequate space and interference from other users is minimal.

**Danish cycle track**  
Suitability for Child/Novice cyclist = ★★★★★  
Suitability for Experienced cyclist = ★★★  
SBF

A Danish cycle track is a sub-type of cycle path which is elevated above the carriageway, for the exclusive use of cyclists, separated from traffic, contained within a road corridor, and adjacent to the footpath (In New Zealand the term track may be confused with mountain bike trails. Therefore, adding the word Danish helps distinguish this type of cycle path which is elevated above the carriageway, for the exclusive use of cyclists, separated from traffic, contained within a road corridor, and adjacent to the footpath. Motor vehicle parking, where provided, is located between the track and the general traffic lanes on the carriageway. As with protected cycle lanes, locating the facility on the passenger side of parked cars reduces car-door opening conflict.

**Shared path**  
Suitability for Child/Novice cyclist = ★★★★★  
Suitability for Experienced cyclist = ★★★+  
SBF

Shared paths can be alongside roads or separate from them, such as in parks or alongside rail lines, rivers, coastlines or lakeshores. They typically feature a sealed surface. They should have good separation from boundaries (to provide improved visibility at driveways), vegetation or other forms of potential side friction (see Error! Reference source not found.).

- Advantages: This facility is useful to cyclists as well as pedestrians, and therefore maximises the benefit of the path to the general community.
- Disadvantages: Conflict between cyclists and pedestrians is common where there is a significant volume of cyclists and pedestrians or a mix of recreational walkers and commuting cyclists. The LOS for cyclists can be poor where interference by other path users results in slower speeds.
- Summary: Shared paths are beneficial to a range of path users but need to be managed effectively. They are appropriate where both cyclists and pedestrians need a path, but their numbers are modest.

**Cycle trail**  
Variable suitability depending on user expectations  
SBF

A trail is typically (but not necessarily) unsealed and located in a public reserve; recreational in focus; located in a rural area; and shared between cyclists, day walkers and campers, and sometimes equestrians. Trails may range from rail-trails or similar formed paths to downhill and cross country uniformed paths suitable for mountain bikes. The term trail is used to describe a pathway intended for recreation, sport and tourism walking and cycling, however “track” is frequently used in New Zealand to mean a mountain bike facility.

**Sealed shoulder**  
Suitability for Child/Novice cyclist = ★★  
Suitability for Experienced cyclist = ★★★★★  
SBF

A sealed shoulder might be used for parking or for emergency stops and may serve as space for cyclists if sufficiently wide. This is typically (but not always) a rural treatment.

- Advantages: Widened shoulders benefit all road users.
- Disadvantages: Sealed shoulders usually narrow at bridges, at passing lanes, and at intersections with turn lanes. Generally, motorists travel at high speeds along roads with sealed shoulders, so cyclists are at significant risk in these situations. Sealed shoulders are sometimes of low surface quality, contrary to cyclists’ requirements.
- Summary: Sealed shoulders provide some benefits to cyclists.
**Bus lane**  
Suitability for Child/Novice cyclist = ★ ★  
Suitability for Experienced cyclist = ★ ★ ★ ★ ★

A lane reserved by a marking and/or sign for the use of buses. Whilst it is desirable that bicycles are accommodated in a separate bicycle lane, examples exist where bicycles have successfully shared in the use of bus lanes. Alternatively, it may be possible to provide a separate on-road bicycle lane or off-road bicycle path adjacent to the bus lane and/or at bus stops. The design of bus lanes must incorporate the needs of cyclists. Bus lanes are not perceived as quality cycling infrastructure by many cyclists (particularly by novice and non-confident cyclists).
- **Advantages:** Bus lanes may be more easily justified than either bus-only lanes or cycle lanes alone, as they benefit both buses and cyclists.
- **Disadvantages:** The LOS is limited, as buses obstruct cyclists by stopping regularly — and in narrow lanes cyclists can prevent buses passing. Lane widths where drivers are unsure whether there is sufficient room to pass, create the conflicts.
- **Summary:** Wide lanes should be used wherever possible so that buses can pass cyclists within the lane.

**Slip lane/cycle bypass**

A facility to avoid a traffic calming device, public transport stop, or intersection control. Bypasses may also be provided at the head of T-junction intersections or as a left turn slip lane (i.e. may be either a mid-block or intersection treatment).

**Wide Kerbside Lanes**  
Suitability for Child/Novice cyclist = ★ ★  
Suitability for Experienced cyclist = ★ ★ ★ ★ ★

- **Advantages:** This facility requires less space than the combined width of a travel lane and a cycle lane.
- **Disadvantages:** Wide kerbside lanes do not highlight cyclists’ legitimate presence on the road.
- **Summary:** Wide kerbside lanes should be considered where no other facility is possible.

The following table lists and describes a number of common *traffic calming* devices, as mid-block facilities, for cyclists and pedestrians. Traffic calming devices are primarily used to encourage drivers to travel at an appropriate speed for their surroundings, and to discourage unnecessary through-traffic.

### Horizontal narrowing

Horizontal narrowing the road profile, including actively removing a lane from the street. It is important to create bypasses for cyclists. Pinch-points are places where the road momentarily narrows, to slow down motorised traffic. When badly designed, street narrowing measures may be uncomfortable or dangerous for cyclists. Cyclists should be able to bypass pinch points in a straight line. The cyclist should not be forced to negotiate the pinch-point together with traffic. Horizontal narrowing can have a significant effect on both speed and the number of vehicles using a street.

### Vertical speed reducers (general)

The most cycle-friendly devices are those that do not take up the entire width of the road, such as speed cushions or bollards to block car access physically. In these cases, cycle bypasses can be provided (allows cyclists to continue on a direct route). Cycle bypasses should have the width of a cycle lane and be clearly marked with a bicycle symbol and appropriate signage.

### Block or restrict access/diverters

Such traffic calming means include: median diverters to prevent right turns or through-movements into a residential area, converting an intersection into a cul-de-sac or dead end, closing of streets to create pedestrian zones. These treatments can, however, inconvenience local residents by requiring them to take a more indirect path to their home.

### Diagonal parking

Diagonal parking may be installed as a simple way of narrowing the road while increasing parking capacity.

### Kerb extensions (buildouts)

Widening the pavement and/or pavement buildouts at intersections or in the mid-block. May be used to reduce the width at pedestrian crossings (good increase in visibility of pedestrians to drivers and approaching vehicles to pedestrians).

### Chicanes

Kerb extensions and/or traffic islands which create a horizontal deflection, used to narrow the width of the roadway in an offset pattern, to create an ‘s’ path that forces traffic to slow.

### Central refuges

Protected place of refuge permitting pedestrians to cross one direction of traffic at a time. Island at the centreline of roadway, at an intersection, or mid-block — usually constructed of concrete kerb, infill with pavers, or landscaping. Generally no or minimal reduction in vehicle speed but good increase in crossing opportunities for pedestrians.

### Speed table

A long hump with a flat space in the middle, long enough to accommodate an entire wheelbase (or more). Often combined with a textured surface. May also be used as a raised pedestrian crossings (often situated at intersections).

### Speed bump

A short, aggressive, rounded hump, spanning the width of the road — suitable for entrance/exit to carparks, esplanades, and service lanes etc... less suitable for use in residential streets.

### Speed humps
A vertical deflection device with a parabolic profile that is less aggressive than a speed bump — can be used on residential streets. Speed humps (generally) are predictably effective at reducing vehicle speed. Bump size and bump spacing affect vehicle speed most. Shorter and closer bumps have the greatest speed reduction.

**Speed cushion**
A narrow hump, not spanning the width of the road, forcing cars to drive over them with one wheel, but allowing vehicles with a wider axle, notably emergency vehicles, to straddle them and drive unhindered. Rubber speed cushions can be used in place of asphalt speed humps or speed cushions as a more visible, easier to transport, and possibly more cost-effective alternative. Rubber speed cushions may have less durability than hard infrastructure treatments and rubber installations may be perceived to have poor aesthetics.

**Surface texture**
Changing the surface material or texture (for example, the selective use of cobblestone) and/or colour.

**Cyclist bypasses**
Cyclist bypasses are generally appropriate where there are: single-lane devices, road narrowings, and devices with abrupt changes in vertical alignment (platforms and ‘speed bumps’). Bypass facilities can often be constructed using the original carriageway surface. Other measures that may be appropriate are: path links at road closures, contra-flow lanes or path links at one-way devices (short cuts).

**Radar speed signs**
Radar speed signs are an interactive sign, generally constructed of a series of LEDs that displays vehicle speed as motorists approach (as installed at several sites around Christchurch). Radar speed signs can result in consistent but modest reductions in the 85th percentile speed, as well as meaningful reductions in the speed of vehicles traveling in excess of the limit (while not interfering with the progress of the majority of traffic that is already traveling at or below the speed limit).
Practical Tool (7) lists and describes a number of the most common intersection treatments that aim to improve cycling and pedestrian levels-of-service and safety. The advantages and disadvantages of selected infrastructure types are discussed in the text, and specific comments are provided as necessary regarding the suitability of certain types of infrastructure for novice/experienced cyclists including children, and for pedestrians. The table is based on existing guides and design manuals, New Zealand legislation and the collective opinions of a range of cycling and pedestrian facility planners and commentators. The table does not comprise a full design guide. For more information and to see this content in context, click on the following link: Intersection treatments for cyclists and pedestrians.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition of Intersection treatments for cyclists and pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paths and foot crossings</td>
<td>Paths provide the network for pedestrian movement on the approaches to intersections and sometimes within large intersections. While paths are essentially a mid-block treatment, they link to and beyond the marked foot crossings at signalised intersections. To be effective the network must provide for pedestrian desire lines and orient pedestrians to correctly navigate intersections.</td>
</tr>
<tr>
<td>Raised-platform/Raised Bicycle Priority Crossing</td>
<td>Raised-platform bicycle and pedestrian priority crossings provide a safe crossing facility for cyclists travelling on off-road paths. This crossing reduces cyclist travel time (by reducing delay at road crossings) whilst improving cyclist safety (improved visibility) at busy roads. The crossings are characterised by a raised platform that is flush with the level of the cycle path. White line marking and signage (“Give way”) warns motorists of the priority cycle crossing while line marking and signage (“Road ahead”) warns cyclists of the road crossing (See Figure 22).</td>
</tr>
<tr>
<td>Storage areas</td>
<td>Medians should provide adequate pedestrian storage where a staged crossing is adopted. The desirable minimum width is that necessary to accommodate a pedestrian with a pram or a bicycle. At left-turn islands and other traffic islands, designers should provide an adequate pedestrian storage area with pathways clear of obstructions. Some form of pedestrian protection may be required in some instances.</td>
</tr>
<tr>
<td>Barnes dance</td>
<td>In CBD areas a separate special pedestrian (&quot;scramble&quot;) phase may be provided in which case the entire intersection is allocated to pedestrian movement each traffic signal cycle.</td>
</tr>
<tr>
<td>Pedestrian crossing</td>
<td>Pedestrian crossings could either be considered a mid-block treatment or a type of ‘intersection’. As the name suggests, pedestrian crossings are generally for the use of pedestrians and dismounted cyclists. However, the ACT Government has commenced a two year trial of riding across pedestrian crossings that commenced on 1 November 2015. The change to allow cyclists to ride across crossings is intended to provide amenity for cyclists, without compromising safety for cyclists and any other road user.</td>
</tr>
<tr>
<td>Tactile Ground Surface Indicators (TGSI)</td>
<td>Tactile Ground Surface Indicators (TGSI) enable visually impaired pedestrians and people with full vision to detect street crossing points, bus stops, and hazardous surfaces or grade changes (warning and orientation functions). TGSI provide a distinctive surface pattern of truncated domes, cones or bars detectable by long cane or underfoot. Warning and directional TGSI can be readily retrofitted in many situations.</td>
</tr>
<tr>
<td>Cycle lane at signalised intersections</td>
<td>The placement of these facilities is complex, however general guidance is provided in ‘Manual of traffic signs and markings (MOTSAM) - Part 2: markings’ NZTA (2009). The section three ‘Intersection pavement markings section 3.18.12 cycle lanes at signalised intersections’ figures 3.36 and 3.37 show appropriate transitions of cycle provision between midblock and intersection locations. The aim is to achieve continuous provisions for cycling. Kerbside cycle lanes must NOT be used where an exclusive left turn lane exists.</td>
</tr>
<tr>
<td>Cycle lane on approach and/or within roundabouts</td>
<td>Not recommended in New Zealand (see discussion below)</td>
</tr>
<tr>
<td>Protected cycle lane on approach to roundabouts</td>
<td>A protected cycle lane, not accessible to cars, and located on the approach and left-turn exit of roundabouts to prevent cycle lane encroachment. The protection may be provided via raised kerbs or other vertical elements. Consideration should be given to the durability of vertical elements employed.</td>
</tr>
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</table>

Kerb ramps
The provision of a gently graded and smooth invert at the gutter is a vital design feature for the safety and comfort of all path users, including cyclists (Figure 10) (Andersen et al., 2012; Austroads, 2009, 2014). In addition, the width of the ramp should match the width of the path, where cyclists need to turn left from the road onto the ramp, or from the ramp onto the road, a satisfactory turning radius (or skew) should be provided, and in some cases flatter kerb ramps of 1 (vertical) in 15 (horizontal) should be considered to provide more efficient and comfortable movement for cyclists between the road and the ramp (Austroads, 2009).

Traffic Signals including cyclist signals
In New Zealand, at intersections without a separate cyclist signal, cyclists have to use the motor vehicle signal. Arrow signals apply to all road users who wish to travel in the direction the arrow indicates. Specific cyclist signals are used in New Zealand but they are not very common. At intersections where cycle lanes of paths continue to the stop line, a separate cyclist signal may be installed (or separate signal light in addition to the main bank of lights/signals). In this way cyclists can have their own signal phase, wholly or partially. Cyclist signals can be used for pre-green for cyclists several seconds before motor vehicles. This can be used to give a separate right turn phase for cyclists, pre-green for straight ahead, ‘free left turn’ or some combination of specific or pre-phases. A ‘head start’ in relation to motor vehicles can render cyclists more visible and reduce cyclist-motor vehicle conflicts.

Parking (restriction of)
Parking is relevant to intersection treatments as the allocation of space to parking on signalised intersection approaches and/or departures can have a substantial impact on traffic operation and performance and pedestrian and cyclist safety. Clearways are often used on arterial roads to maximise capacity during peak periods. Parking should be restricted on the immediate approach to intersections in order to utilise the capacity of the left lane (or use clearways at peak periods) and parking must not impede the required stopping sight distance to pedestrian crossing facilities and pedestrian storage areas.

Special lanes (approaches, through and/or departures of intersections), a ‘queue jump’ lane
Typically, a bus lane at an intersection simply becomes an extension of the mid-block lane, as an additional lane on the approach, or may serve as a queue jump lane that is long enough to enable buses to pass a queue of general traffic and obtain an early start at traffic signals, however, where space is constrained it may be necessary for cyclists to share the lane with buses, possibly creating competition for the same space on the carriageway. Bus lanes (and by extension the space they occupy at intersections) should be signed, marked and delineated in accordance with the relevant standards. At sites where space is available it is preferable to provide a separated bus lane and bicycle lane treatment or a high-standard off-road bicycle path or shared path. A stationary bus waiting or ‘held-up’ within an approach side lane can adversely reduce the sight distance available to other road users and may prevent cyclists accessing a safe queue position (i.e. reaching their advanced stop line or stop box). Bus priority may involve more peak period bus lanes and priority traffic signals for buses, along priority routes and this has the potential to impact negatively or positively on cycle safety and LOS depending on the specific treatments.

Advanced stop box (ASB)
An area in front of a general traffic lane on an approach to a signalised intersection to raise awareness of cyclists by motorists and to give priority to cyclists over other traffic for a particular manoeuvre (NZTA, 2008). ASBs and ASLs have been shown to improve cyclist positioning behaviour. The placement of these facilities is complex, however general guidance to their placement is provided in MOTSAM (NZTA 2009). ASB and ASLs should be coloured green in NZ. Traffic and cycle lane combinations greater than 5.0 m should be avoided (Kooray & Mangundu, 2010).

Advanced stop line
A lane limit line for a cycle lane that is extended beyond the limit lines of other adjacent lanes on an approach to a signalised intersection (NZTA 2009).

Hook Turn Facility
A marked box within the intersection which provides a waiting space for the second stage of a two-stage right turn made from the left side of a carriageway. The Road User Rule amendment (Ministry of Transport, 2009) clause 2.5A formally introduced the hook turn rule to New Zealand and states that a cyclist may enter an intersection by making a right turn or a hook turn. The manoeuvre does not require a marked hook turn box. However, hook turn boxes should be provided to assist cyclists with this manoeuvre as the manoeuvre is unique to cycling and may not be intuitively adopted by all cyclists without the guidance provided by the painted markings. By cyclists keeping left, a hook turn reduces conflict between cyclists and motorists.

Bent-out, Straight and Bent-in pedestrian/cycling side road intersection treatments
There are three types of treatment available for the design of path crossings of side streets, a design where the path approach is bent-out (i.e. is deviated away from the major road), a design where the approach is straight, and a treatment where a one-way bicycle path is deviated to become an on-road bicycle lane. The first two types of treatment may be applied to bicycle paths or separated paths.

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69The New Zealand Road Code for Cyclists describes the hook turn manoeuvre for turning right at a signalised intersection at https://www.nzta.govt.nz/resources/roadcode/cyclist-code/about-cycling/cycling-through-intersections/

70In 2002 the first hook turn trial was undertaken in Christchurch at the Greers Rd / Memorial Avenue intersection near Burnside High School.
Structures
A number of structures are used in association with cycle provision, such as bridges, underpasses and overpasses. Site topography may favour either a bridge or an underpass. Because structures are expensive, the needs of cyclists and others must be properly identified, particularly in relation to: constructing a motorway, planning new residential areas, and designing a structure (opportunities for retro-fitting structures are probably limited).

End-of-trip facilities
End-of-trip facilities (such as secure parking, lockers and showers) and trip facilities such as shelter, water and toilets are important infrastructure for cyclists.
Practical Tools (8 & 9) relates to planning and design considerations that influence the ways in which bikes and buses co-exist along the roadway. With regard to safety, generally, bus-cyclist crashes are characterised by a high proportion of angular crashes at non-intersection locations. In particular, a substantial proportion of angular crashes are related to lateral movement of buses in the roadway. The list below outlines the most common bus-bike conflicts within a typical road network. For more information and to see this content in context, click on the following link: Public transport (Bus).

Practical Tool (8) Regular and difficult interactions between buses and cyclists

<table>
<thead>
<tr>
<th>Blind spots and swept path conflicts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus turning movements can pose ‘blind-spot’ and ‘swept-path’ issues; especially where the bus is making a left turn from a dedicated left-turn lane and lane geometry is inadequate for the bus to remain totally within the turning lane. This especially important for cyclists travelling straight through the intersection as they will usually be close to the left of this lane.</td>
</tr>
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<table>
<thead>
<tr>
<th>Roundabouts</th>
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<tbody>
<tr>
<td>Roundabout design is a key issue for buses and bicycles both in the context of their interaction, and individually. The appropriate solutions for one might compromise safety and convenience for the other. The issues may also vary depending on the size of the roundabout, i.e. those with only a single circulating lane compared to those with two or more. Solutions include ‘bus bypass’ options.</td>
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<table>
<thead>
<tr>
<th>Signalisation conflicts (bus priority lights)</th>
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</thead>
<tbody>
<tr>
<td>Use of ‘B’ bus priority lights can cause conflicts in/around a bus lane (which may be used by cyclists): a bus driver may be unaware of a cyclist still in the intersection (e.g. when completing a Hook Turn as the cyclist may not arrive until after the lights for turning/intersecting traffic have turned green).</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Young or Inexperienced Cyclists</th>
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</thead>
<tbody>
<tr>
<td>Young and/or inexperienced cyclists are least able to cope with complex traffic environments. Such manoeuvres as safely merging into the general traffic lane to pass a stopped or stopping bus are likely to be beyond the skill and speed capabilities of young and/or inexperienced cyclists (potentially placing young and/or inexperienced cyclists at great risk).</td>
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<thead>
<tr>
<th>Bus exchange entry and exit</th>
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</thead>
<tbody>
<tr>
<td>The entry and exit points for bus stations inevitably have high concentrations of bus movements often in complex environments involving turning and other vehicle manoeuvres.</td>
</tr>
</tbody>
</table>

Practical Tool (9) is an example of a specific Cycle Audit checklist that can be applied to proposals that have potential impacts on the convenience or safety of cyclists. To make a cycle audit more specifically appropriate to proposals for bus priority, the additional items listed below can be considered (see also Austroads, 2005, p.45).

- If a bus lane is proposed, will cyclists be allowed to use it, and if they will, will the bus lane be of sufficient width to accommodate buses and cyclists. If they will not, is there an alternative route that is suitable for cyclists?
- If other forms of bus priority are proposed, what are the impacts on cyclists? Does the bus priority restrict access for cyclists or put cyclists in more vulnerable positions in the roadway?
- Have bus stops and bus shelter locations been designed to allow the safe passage of bicycles past them?
- Where buses are required to turn next to cyclists, does swept path of the buses encroach upon the cyclist’s road space?
- If ‘B’ bus priority lights are proposed, has consideration been given to the needs of cyclists?

### Practical Tool (10): A three-level checklist of cohesiveness, general planning and safety

#### COHESIVENESS
- To what extent does the proposed infrastructure initiative contribute to overall network cover? Does the proposed pedestrian/cycling infrastructure link residential areas with primary pedestrian/cycling destinations such as schools, educational institutions, employment and retail centres, entertainment venues, sports facilities, and traffic terminals (i.e. key activity areas) as well providing links to the surrounding communities? Does the plan embody Link-Place planning principles?
- Has an overall hierarchy been established that gives priority to primary routes rather than side streets and local routes, so that the majority of cyclists are attracted to primary routes?
- Are school route plans purposefully coordinated with the overall surrounding cycling infrastructure plan?
- Are the routes direct (additionally, can shortcuts be provided to make it faster to bike than drive on local journeys)?
- Does the existing pedestrian and cycling infrastructure live up to the newest construction standards (i.e. will the new infrastructure fit cohesively with existing infrastructure)? For example, an individual intersection’s design is often characteristic of the period of its construction and upgrades might be needed to the existing infrastructure and/or to the design of the new infrastructure to conform to a uniform standard (cohesiveness considers the broader aspects of level-of-service, not just pedestrian and cyclist safety in isolation).
- Does the plan accommodate experienced as well as vulnerable cyclists? (e.g. a direct but heavily trafficked road may be acceptable for adult cyclists but not for school children).
- Is the flow broken (e.g. by poor lighting, barriers, too many signalised intersections or poor maintenance)?
- Is the mesh size of the urban cycling infrastructure appropriate (the mesh size should be smaller in the city centre and larger in the periphery)?
- Are there options for recreational cyclists, ‘fitness’ cyclists and cycle tourists that provide an active experience and a high level-of-service?
- Has consideration been given to unintended consequences such as displacement, ‘short cutting’ or physical barriers to access for the elderly or disabled people (are traffic calming treatments/threshold treatments such as cul-de-sacs, chicanes, humps, and road narrowing, appropriate)?

#### GENERAL PLANNING PRINCIPLES
- Is the proposed design appropriately in accord with the principle of ‘traffic differentiation’ (segregation of different types of traffic, with the hierarchical road system as a main system solution) and/or ‘traffic integration’ (using traffic calming with filtering of car traffic to create mixed-use urban streets as the main objective)?
- Is the proposed specific infrastructure plan consistent with any broader village-level ‘Master Plan’ (such as a plan that is aimed to provide a pedestrian-friendly environment)?
- Does the proposal improve passability, access and security of the transport network?
- Does the proposal enhance the carriageway as a ‘self-evident road’ (meaning that the road design should guide the road user’s attention to possible conflict areas)?
- Is the proposed design adequately supported by traffic calming infrastructure?
- Are cyclists and pedestrians likely to experience unnecessary delays in intersections? Are cyclists and pedestrians on equal footing with car and bus?
- Does the proposal enable and encourage citizens and employees to cycle rather than drive (are their specific elements of the plan aimed at influencing user behaviour)?
- Does the proposal include an explicitly stated objective of increasing pedestrian and cyclist safety and increasing active transport mode share (by a specified percentage)?
- Does the proposal explicitly seek to reduce CO2 emissions, benefit the environment, and improve public health?
- If the infrastructure is initially established to a relatively low standard, have provisions been made for improvements over time?

#### SAFETY AUDIT
- Is the selected type of intersection(s) suitable?
- Is the selected approach to the mid-block treatments suitable?
- Are 30 km/h speed limits required to ensure adequate overall safety?
- Is there a need for extra segregation between the cycle lanes/paths and parked cars (e.g. when opening car doors)?
- Are cycle paths (not lanes) planned for roads with fast moving traffic?
- Has the placement of right-turning cyclists in intersections been taken into account (particularly roundabouts)?
- Does the signal timing sufficiently take cyclists and pedestrians into account (including placement/type of detectors)?
- Have special cycle phases (e.g. ‘pre-greens’ or arrows) been incorporated in the design if needed (in addition to ‘standard’ pedestrian phases)?
- Is there a need for special measures to point out give-way rules and/or manage potential conflicts between other road users and cyclists, such as textured and/or raised areas, special surface colour (green), rumble strips?
- Can cyclists wholly or in part be exempt from signalisation (e.g. on left turns or straight through the ‘top of the tee’)?
- Are traffic islands wide enough for waiting cyclists/pedestrians (adequate storage areas)?
- Are there safe waiting and boarding and disembarking areas for bus passengers (i.e. managing potential conflicts with other road users)?
- Is the road surface in satisfactory condition at crossings and on the adjacent cycle paths?
- Are there gully grates or other surface (or overhanging) obstacles on the cycle route?
- Does the design of a two-way cycle path (and/or shared path) provide cyclists with a clear line of sight to oncoming path users in order to prevent dangerous situations (including, in the case of shared paths, adequate sight lines to residential driveways)?
- Two-way cycle paths (and/or shared paths) along roads should be avoided if there are more than very few side roads/private driveways.
- Do all the kerb ramps on the bicycle facilities have a satisfactory turning radius (or skew), a suitable gradient, and a ‘smooth invert’ to provide efficient and comfortable movement for cyclists between the road and the ramp?
- Do all painted infrastructure elements conform to the relevant standards (and are/will the adjoining streets be treated consistently e.g. changing red painted lanes to green)?

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Adapted from: [Andersen et al., 2012; Austroads, 2013, 2014a; Christchurch City Council, 2013; Jones & Boujenko, 2011; Koorey & Mangundu, 2010; Pucher, 2001]