Path speed management devices

Research on accessibility impacts

JUNE 2025

REPORT PREPARED FOR:
NZ Transport Agency Waka Kotahi

VIASTRADA
TRANSPORT PLANNING AND DESIGN

Quality Assurance Statement		
ViaStrada Ltd Level 1, 284 Kilmore Street Christchurch 8140 New Zealand www.viastrada.nz	Project manager:	John Lieswyn, MET, PTP, CM-CIHT Director – Principal Transportation Planner 021 266 2929 john@viastrada.nz
	Prepared by:	Luca Ware John Lieswyn David McCormick
	Reviewed by:	Glen Koorey
Project number: Project name:	1090-32 Path speed management devices	

Document version	Date
V7 (incorporating client final review)	26/06/2025
V6 (synced with guidance note changes)	27/05/2025
V5 (additional bus stop bypass and rumble strip sites)	25/06/2024
V4 (additional data collection and updated figures)	1/12/2023
V3 (adds dimension “E” for barrier overlap)	5/01/2023
V2	4/08/2022
V1 draft (For client comments)	26/05/2022

All images are by the authors unless otherwise noted.

Executive summary

Waka Kotahi New Zealand Transport Agency commissioned ViaStrada to determine the speed reduction effectiveness and any potential adverse effects of horizontal deflection treatments on paths and include vertical deflection treatments for cycle-only facilities.

In this report, speed management devices on paths for bikes and other forms of micro-mobility were investigated and measured. These devices are usually implemented in advance of conflict points (e.g. with trains at railways or with motor traffic at roads). They may also serve as a form of access management to prohibit unauthorised motor vehicle access.

Speed management devices are intended to work by slowing path users down, alerting path users to the potential conflict, or both. However, overly restrictive devices may be counterproductive. For example:

- a railway maze may have signage instructing users to “LOOK FOR TRAINS” but riders are too busy manoeuvring through the maze to do so
- a path end terminal chicane at a roadway may be so tight that certain types of bikes or prams cannot access the path, unreasonably delay users, or create conflict between path users

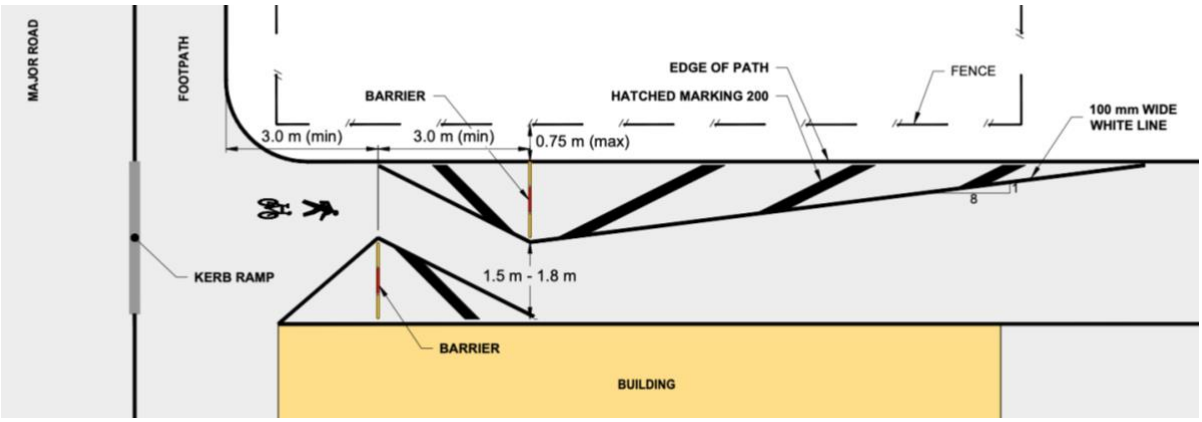
This observational study aimed to measure speed and accessibility at a range of treatment types, including mazes and chicanes designed using current NZ Transport Agency and KiwiRail guidelines. To increase the number of layouts that could be included in this study, simulated speed reduction treatments (using moveable planter boxes) were also temporarily applied on a path.

Vertical deflection as designed at the test sites was relatively ineffective in significantly reducing path user speed. No real mazes were tested but the simulations showed that the tighter mazes are unacceptable from an accessibility standpoint. Chicanes had the most effect on speed, but also may prevent legitimate access and create inconvenience.

The results of this investigation point towards some of the current guidelines being too restrictive of speed and access while other treatments have little impact on speed but may be achieving the goal of alerting riders to the potential conflicts ahead.

The most frequently used devices for path ends are bollards (aka “access control devices”), but these are not speed control devices and a separate NZ Transport Agency document discusses these in more detail.

This study led to the development of a preferred layout for chicanes (see below) that provide both access control and speed management.



Sample layout for a chicane that manages speed while permitting negotiation by all users

Table of Contents

1 Introduction

1.1 Project objective

Waka Kotahi New Zealand Transport Agency has commissioned ViaStrada to determine the speed reduction effectiveness and any potential adverse effects of horizontal deflection treatments on paths and include vertical deflection treatments for cycle-only facilities.

1.2 Outcomes

This research is intended to inform the planning and design of deflection devices used on paths at:

- path end terminal treatments (e.g. where they meet roads, railway crossings etc.)
- transitions to slow-speed shared spaces (e.g. 40 to 30 or 30 to 20 km/h)
- other places where speed needs to be reduced

This information will help readers understand the impact on speed and accessibility, safety and comfort for a range of devices with various wheelbases and wheel sizes. The learnings may be used to update the Pedestrian and Cycling Network Guidance and *Section 8.0 Requirements for pedestrian and cycle level crossings* in the *TCD Manual* *Part 9 Level Crossings* (NZ Transport Agency, 2012).

1.3 Background

ViaStrada and Mackie Research were previously commissioned to study the effects of signs and markings for speed reduction. The results were generally inconclusive, with only one treatment (KEEP LEFT marking, a large SLOW roundel and red blocks) showing a roughly 10% speed reduction and a lateral positioning effect. The treatment effectiveness was found to be location specific.

There remains a need to develop consistent national guidance on how to manage rider speeds along paths and on the approach to conflict locations and hazards. This will help avoid the installation of treatments that are ineffective and more 'aggressive' than necessary (may result in adverse safety or discomfort for path users).

No guidance on the impact of vertical deflection (for example, how much of a change in gradient impacts cyclists) currently exists. Austroads guidance outlines how different curve radii can impact a cyclist's speed (the underlying theory behind horizontal deflection). Waka Kotahi and KiwiRail also developed guidance for physical calming of pathway level crossings based on geometric principles (e.g., Figure 2-4). This study was informed by the following publications:

- *Horizontal geometric design for mobility scooters* (Waka Kotahi NZ Transport Agency, 2021b)
- *Access control devices on paths* (Waka Kotahi NZ Transport Agency, 2020)
- *Section 8.0 Requirements for pedestrian and cycle level crossings* in *TCD Manual* *Part 9 Level Crossings* (NZ Transport Agency, 2012)
- *Design Guidance for Pedestrian & Cycle Rail Crossings* Version I (KiwiRail & NZ Transport Agency, 2017)
- *Distracted Users Report* – unpublished (Stantec, 2018)
- *Cycle Trail Design Guide* 6th Edition (MBIE, 2024)
- *A guide to controlling access on paths* (Sustrans, 2012)
- *Traffic-free routes and greenways design guide – Section* *9. Access to routes* (Sustrans, 2019)
- *London Cycling Design Standards* (Transport for London, 2016)
- Auckland *Transport Design Manual* – for bus stops (Auckland Transport, undated)
- Austroads and CROW design guides (various)
- Guide for the Development of Bicycle Facilities, 4th Edition, 2012 (AASHTO, 2012)
- *Guide to Inclusive Cycling* (Wheels for Wellbeing, 2020)
- *Path behaviour markings guidance note* (Waka Kotahi NZ Transport Agency, 2021a)

- Accessible cycling infrastructure: design guidance note (Waka Kotahi NZ Transport Agency, 2024)

1.4 Design requirements

The minimum speed for e-scooter stability is about walking pace. They are quite easily controlled and steered at very low speeds. Billstein and Svernlöv (2021) found that:

> *"The e-scooter had good stability and comfort at both high speed and low speed. The e-scooter had a significantly lower steering rate than the bike at both low and high-speed indicating high stability performance. The e-scooter also performed well in terms of manoeuvrability since it needs a smaller steering angle than the e-bike and the bike to perform the slalom course. The e-scooter acceleration was lower than the e-bike, but comparable with the bike."*

The larger wheels and higher centre of gravity for adults' bicycles mean a higher speed is required to maintain control. The larger the wheel, the more gyroscopic force needs to be managed to change direction. The minimum speed for an adult cyclist will depend on their skill level and the bicycle type. Even for skilled riders, a cargo bike is difficult to ride through chicanes and mazes due to their longer wheelbase and larger turning radius. CROW (2016) says:

> *The lower limit for curve radii is 5 m; in the case of smaller values the cycling speed will fall below 12 km/h and older cyclists in particular will have to exert more effort to remain upright. (p.51)*

Children were found to be able to remain stable at an average speed of 10 km/h in NZMJ research note Children cycling on footpaths (Randal et al., 2018). Accordingly, the research on which this technical note is based sought to determine what treatments and layouts are effective in reducing rider speeds from typical free speeds to no less than 10 km/h.

The size and minimum turning circles of various cycles and scooters is shown in Table 1-1, based on manufacturer's published specifications, field measurements and prior research (Department for Transport, 2020; Waka Kotahi NZ Transport Agency, 2021b). The minimum turning circle inner radius is what the vehicle can achieve at a minimum rolling speed, not a riding speed.

Table 1-1: Size and minimum turning circles of cycles

Type of vehicle	Max. length (m)	Max. width (m)	Minimum turning circle (m)	
			Outer radius	Inner radius
Cycle design vehicle	**2.7**	**1.0**	**3.6**	**2.5**
Standard cycle	1.80	0.75	1.65	0.85
Cargo bicycle (front loader)	2.65	0.75	2.70	1.90
Cycle plus 850 mm wide trailer	2.70	0.85	2.65	1.50
Tandem	2.40	0.65	3.15	2.25
Trike (3-wheel cycle, handcycle)	2.05	0.86	3.50	2.50
Mobility scooter (95th percentile)	1.57	0.77	3.60	1.80

Standard cycle dimensions are used as the design vehicle and the maximum dimensions are used as the "checking vehicle". The latter means that the largest vehicles can still negotiate the device but at a slower speed. Turning path analysis is done using the centreline of the vehicle path, with the inner radius used to exclude layouts that would prevent access by the checking vehicle.

2 Types of deflection

2.1 Deflection principles

Deflection, both vertical and horizontal, aims to use the environment to slow transport users. This can be an unintentional hill, hump (vertical deflection) or corner (horizontal deflection). Deflection principles for walking and cycling differ from motor vehicles due to the huge range of cycling abilities, bike styles, free flow speeds, manoeuvrability and intended path uses (shared path or cycle lane). Horizontal and vertical deflection layouts generally follow (but are not limited to) the forms shown in Figure 2-1.

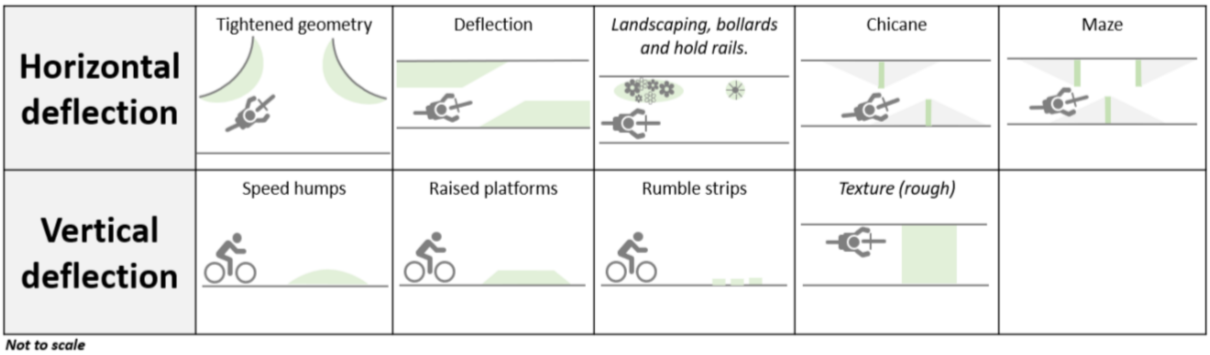


Figure 2-1: Cycle calming techniques (adapted from figure 4.20 in London [Cycling Design Standards](#) 2016)

2.2 Vertical deflection

Vertical deflection is sometimes used on separated cycle paths or cycleways but is often present naturally (in the form of vertical climbs). It is not desirable for shared paths due to the potential for tripping pedestrians and the discomfort for cyclists who are unable to stand out of their saddle (i.e., hand cyclists) but is still sometimes used (Figure 2-2). Temporary structures for vertical displacement are likely to cause damage to the path surface due to fixing methods and potentially dangerous if not implemented properly. Therefore, only existing treatments were tested. Vertical deflection was tested on a shared path (Figure 2-2) and separated cycle lanes (Figure 2-3).

Figure 2-2: Yaldhurst Road bollard, rumble strips and horizontal curves (Site V1)

Figure 2-3: Tuam Street speed hump (Site V4)

2.3 Horizontal deflection

2.3.1 Narrowing and/or path curves

Bus stop bypasses generally incorporate some degree of narrowing and/or path curves to detour around a bus shelter. Section 13 of the Auckland Transport TDM presents recommended angles and dimensions, and Christchurch bus stop bypasses are similar. Some Christchurch separated cycle lanes at bus stops do not have any curves, instead using red surface colour and a raised platform.

Curves can also be used without any maze or chicane barrier to manage speeds (see Figure 2-4).

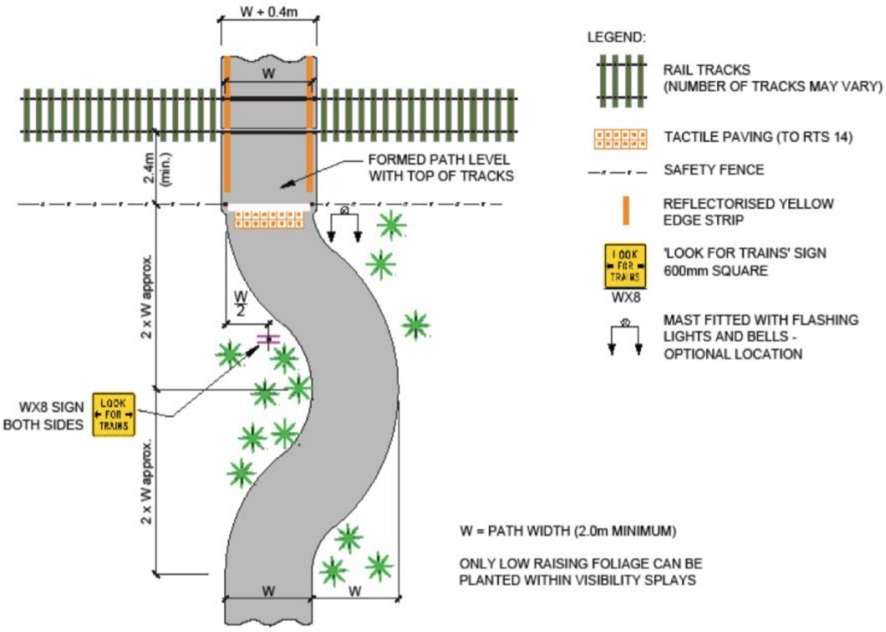


Figure 2-4: Horizontal deflection specified by design guidance for rail crossings (Fig.46 in KiwiRail guide)

2.3.2 Chicanes

Waka Kotahi's TCD Manual: Definitions defines a chicane as:

> *The lateral movement of traffic from one line or one or more lanes onto another alignment before a shift back toward the original road alignment, but not necessarily into the original line, lane or lanes.*

Existing local chicanes were tested for speed change (Figure 2-5 and Figure 2-6 show testing sites). Figure 2-7 shows the KiwiRail recommended layout for a chicane. Handrails and staple barriers are often used to create the deflection needed for a chicane.

Figure 2-5: Chicane, Grove Road (Site C1)

Figure 2-6: Chicane, Winters Road (Site C2)

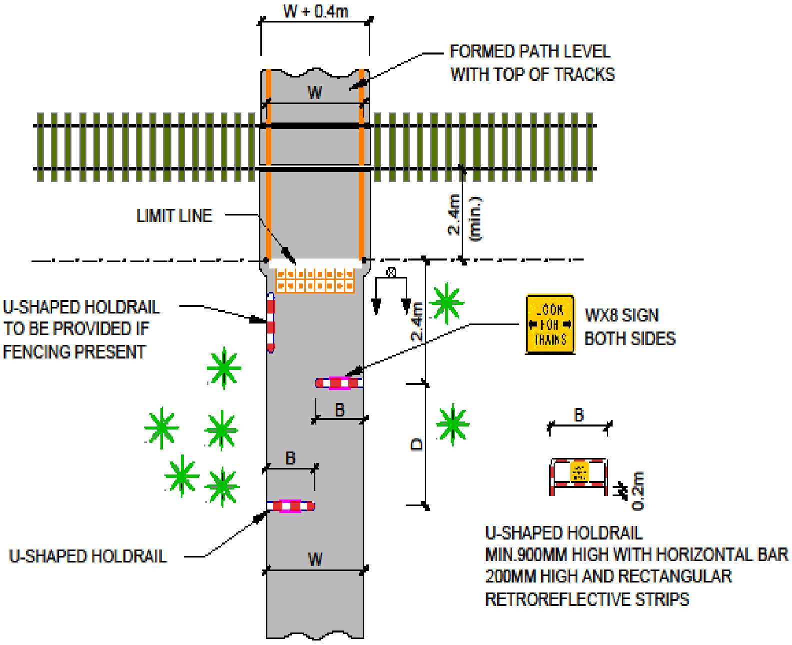


Figure 2-7: Layout plan for a handrail deflection chicane (Figure 48 in the KiwiRail guide)

Because mazes theoretically lower speed more and force awareness of oncoming traffic through orientation change, they are often used at points of conflict with higher traffic volumes or speeds. Mazes are typically found at railway crossings, while chicanes are commonly found at road crossings.

The New Zealand Cycle Trail Design Guide (MBIE, 2024) identifies the different types of treatments at railway crossings (section 4.6). Grade separation is the preferred option. If the crossing must be at-grade, treatments (in order of preference) are automatic barriers, audible and visual warning (flashing lights and bells), physical calming (e.g. chicanes or mazes on the approaches), and simple passive control (signs and markings only). If the approach angle is 90 degrees, treatment may not be needed.

2.3.3 Mazes

Waka Kotahi's TCD Manual: Definitions – defines a maze as:

> *A device installed on the approaches to a level crossing, most commonly where there are two or more railway lines, for pedestrians and riders of mobility devices, wheeled recreational devices or cycles that redirects them at right angles toward the direction any approaching train would be and then at a right angle in the opposite direction to permit them to proceed across the level crossing.*

Figure 2-8: Maze approaching Ilam Road (Site M1)

Figure 2-9: Blenheim Road railway maze (Site M2)

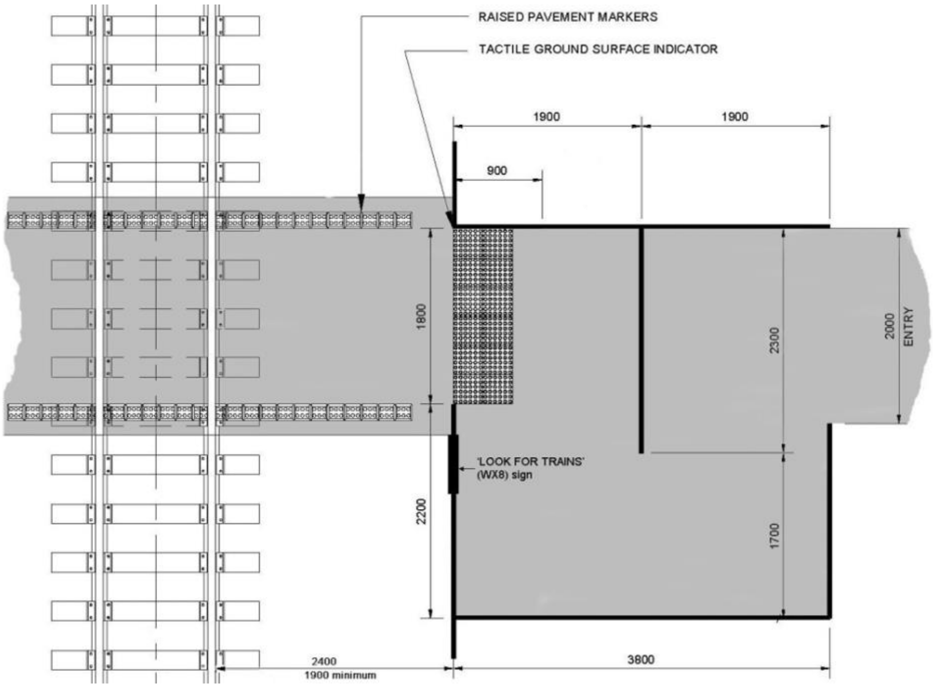


Figure 2-10: Typical pedestrian maze for level crossings (Figure 8.1 in TCD Manual Part 9, NZTA 2012)

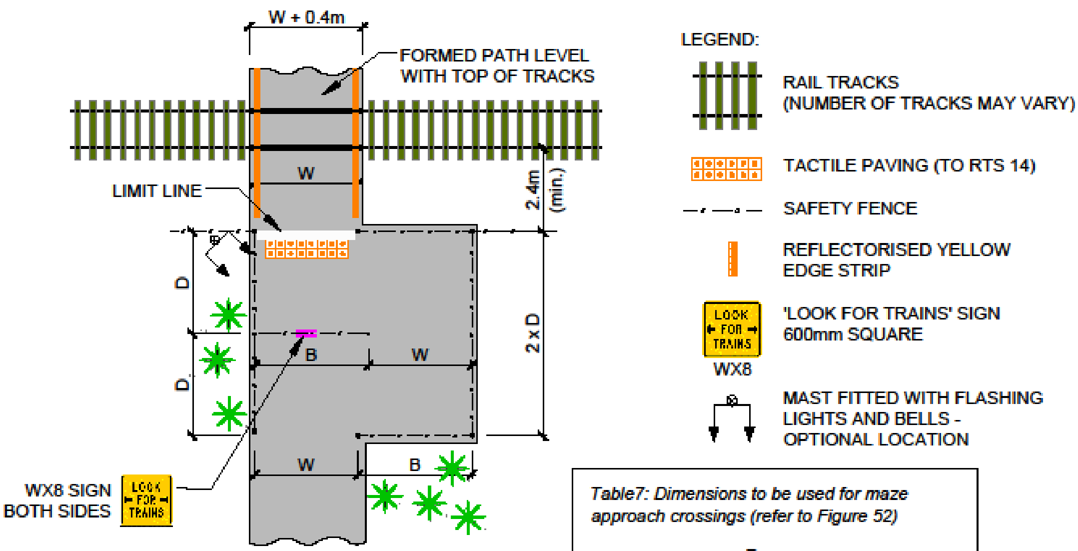


Table7: Dimensions to be used for maze approach crossings (refer to Figure 52)

	Parameter		
	W (m)	*D (m)*	*B (m)*
Maze 1	2.0m*	2.0	2.3
Maze 2	2.5	2.5	2.8
Maze 3	3.0	3.0	3.3
Maze 4	3.5	3.5	3.8

*For pedestrian-only crossings

Figure 2-11: Layout plans for mazes (Figure 52 in KiwiRail 2017, with maze numbers added for reference)

Typically, the layout plans in the TCD Manual (Figure 2-10) would be considered insufficient for cycle or shared paths The KiwiRail guide (Figure 2-11) indicates 2.0 m wide paths are for pedestrian-only crossings. However, many crossings or locations approaching areas of conflict are shared use or later designated for shared use.

2.3.4 Horizontal deflection terminology

Barriers are often installed at least 0.1 m from the edge of the path and their ends near the centre of the path may overlap one another; in this report that dimension is known as "**O**". Path width (**W**) may vary depending on the layout (chicane, maze, etc) – in some cases it is the total path width, in others it is the clear traversable width from the end of a barrier to the edge of path. Other key variables are listed below in Table 2-1.

Table 2-1: Key layout dimension variables

Dimension variable	Description
D	Barrier ***spacing***, longitudinally measured along the path
B	***Barrier*** width, transverse to the direction of travel along the path
O	Barrier ***overlap***, between the inner ends of the barriers
W	Path ***width***
E	***Effective*** path width, between edge of path and inside end of barrier

The diagrams shown in Figure 2-12 illustrate variations on layouts for the inner ends of the barriers that form a chicane (for a maze, add another barrier). A zero value of **O**(0) means no overlap or gap and is preferred; a positive value of **O**(+) means some overlap, which is not always recommended; a negative value of **O**(-) means a clear gap through and may be required if there is not enough room for the minimum depth **D**.

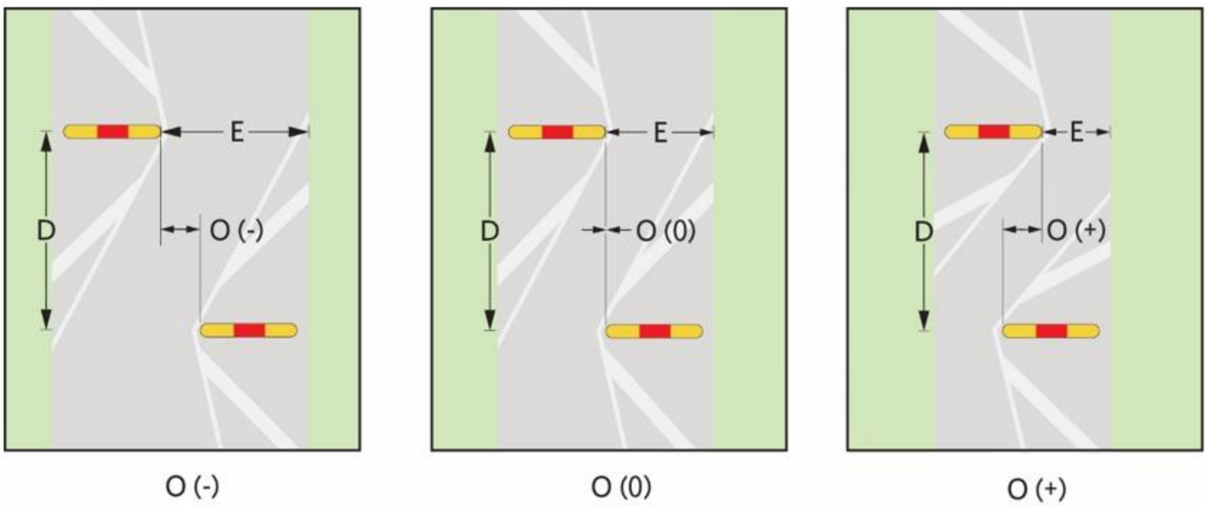


Figure 2-12: Illustration of variation in O (overlap). O (0) is preferred (i.e. no overlap). O(+) may block path access for mobility device users, particularly where the path is narrow.

3 Research study

3.1 Sites

Table 3-1 lists details of the sites where testing was undertaken, including an embedded photo reference for each.

Table 3-1: Site list ("Est. ADT" is estimated daily cyclist volume)

	Description	Hazard	Vertical geometry	Horizontal geometry	Site ID	Location	Est. ADT
Rumble strips	Bollard, rumble strips and curves on shared path	Road	15 mm strips & bollard	10 m radius S-curve	V1	417 Yaldhurst Rd	50
	A short platform about 30 m before rumble strips on 1-way cycleway	Driveway	100 mm high, 1:20 ramp 30 m before 15 mm strips	n/a	V2	133 Tuam St	500
	Rumble strips and slight curve on 2-way cycle path	Driveway	15 mm strips	Not significant	V3	26 St Asaph St	500
Hump	Incorrect hump markings; can be bypassed in gutter	Zebra to bus stop	50 mm high, 0.8 m long	n/a	V4	Tuam / High St	500
Bus stop platform	Recent additions of red flush warning stripes	Zebra to bus stop	100 mm high, 1:20 ramp	n/a	B1	164 St. Asaph St	500
	Followed by curved approach to side road	Zebra to bus stop	100 mm high, 1:20 ramp	n/a	B2	961 Colombo St	300
	Recent; smooth transitions from cycle lane	Bus stop bypass	100 mm high, 1:30 ramp	20 m radius S-curve 2 m path	B3	90 Ilam Rd	700
	Older; constrained width from cycle lane	Bus stop bypass	150 mm high, 1:20 ramp	15 m radius S-curve 1.5 m path	B4	122 Ilam Rd	700
	Recent; bus stop bypass with a 1.5 m wide island and raised platform	Bus stop bypass	100 mm high, 1:10 ramp	n/a	B5	50 Park Tce	500
Chicane	Chicane with approach curve on 2-way cycle path	Railway	n/a	D = 3.1 O = +0.7	C1	Grove Rd	500
	Chicane on shared path	Motorway off-ramp	n/a	D = 2.0 O = -0.4	C2	Winters Rd	50
	Chicane on shared path; can be bypassed in grass; Streetview predates upgrade	Street	n/a	D = 3.0 O = 0	C3	NW Arc at Rose St	300
Maze	Maze at Ilam Fields on high use shared path	Pedestrian crossing of road	n/a	D = 3.5 O = 0	M1	Ilam Road at Ilam Fields	700
	ALCAM ID 2196 as studied by Stantec; shared path	Railway	n/a	D = 2.5 O = -0.3	M2	Blenheim Rd xing	400
	Simulation area in Chch "red zone" *(Street view is pre-earthquake)*	Simulated (see section 3.2.2)	n/a	Various	M3	Avon Loop path	300

Figure 3-1: 417 Yaldhurst Rd (V1)

Figure 3-2: 133 Tuam St (V2)

Figure 3-3: 132 St Asaph (V3)

Figure 3-4: Tuam and High St intersection (V4)

Figure 3-5: 164 St. Asaph St (B1)

Figure 3-6: 961 Colombo St (B2)

Figure 3-7: 90 Ilam Rd (B3)

Figure 3-8: 122 Ilam Rd (B4)

Figure 3-9: Park Terrace (B5)

Figure 3-10: Grove Rd (C1)

Figure 3-11: Winters Rd (C2)

Figure 3-12: NW Arc Cycleway (C3)

Figure 3-13: Ilam Road (M1)

Figure 3-14: Blenheim Rd, north of 6 Pope St (M2)

Figure 3-15: Red zone path (M3)

3.2 Methods

3.2.1 Observational methods

The primary data (LiDAR speed and comfort ratings) was recorded in the field using cloud-based spreadsheets preformatted for rapid and consistent analysis, based on our developed experience doing similar research for cycle speed and gender surveys.

Table 3-2: Collected data

Data type	Method	Notes
Speed on approach to and at the treatment device	LiDAR speed gun	Near-instantaneous readings accurate to ± 1 km/h
Comfort and usability	User observations from informed participants	A Likert scale was derived from *"it didn't slow me down at all – basically unnoticeable"* to *"I had to stop and/or dismount to get through"*

About 300 public observations were collected and five passes undertaken for each controlled, informed study team member. Each site required about one hour to obtain photos, measurements, and observations. The study participants are listed in Table 3-3.

Table 3-3: Study participant details

Participants	Speed data	Comfort rating
General public (at sites and treatments where this is possible)	Yes	No
John Lieswyn, experienced; front loader e-cargo, road bike, e-scooter	Yes	Yes
Luca Ware, beginner; on standard mountain bike	Yes	Yes
Azrie Azizi, intermediate; e-scooter	Yes	Yes
Amy Dunn, intermediate; town (utility) bike	Yes	Yes

3.2.2 Simulated mazes

Plywood "planter boxes" of a similar height to maze rails / fences were used to simulate different horizontal deflection lateral and longitudinal layouts (Figure 3-16 and Figure 3-17). These materials allowed easy setup and changes of independent variables.

Figure 3-16: Testing of simulated mazes

Figure 3-17: White landscape chalk showing all maze simulated layouts

4 Results

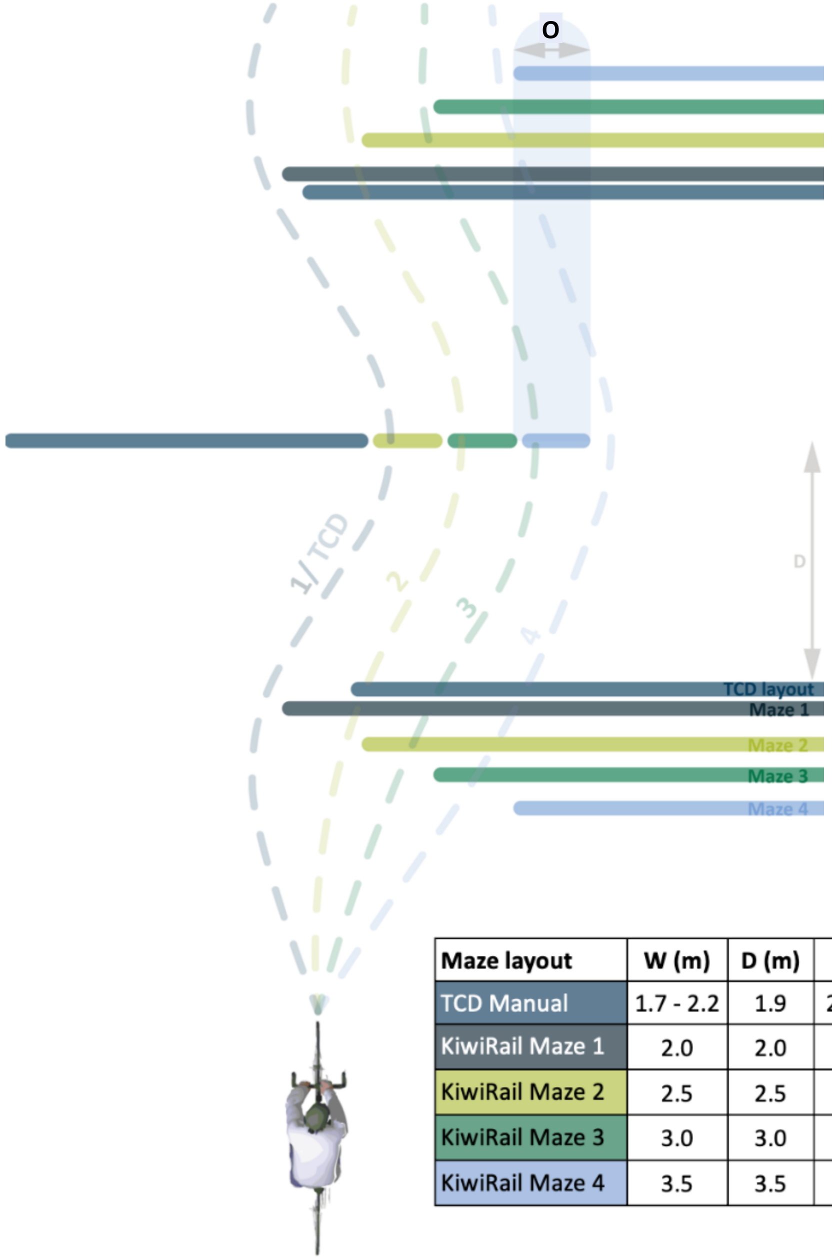
Table 4-1 outlines the locations, speed changes (in km/h) and summary observations. Speed changes (in km/h) that were positive may be due to distance from a nearby intersection (i.e., the riders were speeding up through the midblock). At the chicanes and mazes, some riders had to fully stop for other path users already in the device. These observations were excluded from speed change assessment.

Table 4-1: Results from observed sites

	Description	Vertical geometry	Horizontal geometry	Site ID	Location	Sample size	Speed change	Assessment
Rumble strips	Shared path to road	15 mm strips Bollard	10 m curve	V1	417 Yaldhurst	6	-11.7	Poor comfort / all bikes slowed; trikes may be blocked
	Cycleway to driveway	100 mm, 1:20 15 mm strips	n/a	V2	133 Tuam St	63	+1.5	Warning only. 60% bypass rate
	Cycle path to high-use driveway	15 mm strips	n/a	V3	132 St Asaph St (PB Tech)	52	-0.2	Warning only. 56% bypass rate
Hump	Cycle path hump to bus stop zebra	50 mm high, 0.8 m long	n/a	V4	Tuam / High St	48	-1.3	Warning only. 6% bypass rate
Bus stop platform	Cycleway platform to bus stop zebra	100 mm, 1:20 ramp	n/a	B1	164 St. Asaph St	26	-0.3	Riders slowed only for bus patrons
	Cycleway platform to bus stop zebra	100 mm high, 1:20 ramp	n/a	B2	961 Colombo St	16	+1.4	Riders slowed only for bus patrons
	Cycle lane bypass of bus shelter	100 mm high, 1:30 ramp	20 m curve 2 m path	B3	90 Ilam Rd	12	-2.4	Pedestrian conflict unlikely here
	Cycle lane bypass of bus shelter	100 mm high, 1:20 ramp	15 m curve 1.5 m path	B4	122 Ilam Rd	8	-2.8	Slowing perhaps due to narrow path
	Cycleway bypass of bus island	150 mm high, 1:10 ramp	30 m curve 2.8 m cycle	B5	50 Park Tce	43	-0.3	Warning only. 3 riders went around in traffic lane
Chicane	Cycle path to railway	n/a	D = 3.1 O = +0.7	C1	Grove Rd	53	-5.1	No practical effect – reduction is due to congestion
	Shared path to motorway off ramp	n/a	D = 2.0 O = -0.4	C2	Winters Rd	26	-9.8	Tight chicane forces larger bikes to stop; discomfort for all
	Shared path to street	n/a	D = 3.0 O = 0	C3	NW Arc at Rose St	*n/a*	-	*Warning only. No survey undertaken*
Maze	Shared path to pedestrian xing	n/a	D = 3.5 O = 0	M1	Ilam Road at Ilam Fields	53	-7.3	Minor geometric effect, reduction is due to congestion
	Shared path to railway	n/a	D = 2.5 O = -0.3	M2	Blenheim Rd xing	*n/a*	-	*Could not obtain permit for survey*
	Simulation area	n/a	Various	M3	Avon Loop path	19	-12.9	Refer to following separate analysis

Figure 4-1 shows the layouts and speed through treatment ranges of the simulated maze treatments and how these layouts compare to one another. The speed ranges in the legend are based upon multiple passes at a relaxed speed, a confident commuting speed, and the maximum possible speed (coming as close to the apex points of each curve as could be managed).

The various barrier widths (**B**) specified in related guides such as the TCD Manual and KiwiRail guidance are not relevant as path width (**W**) will vary. The key aspect relating to navigability is inner barrier end overlap (**O**+) and barrier longitudinal spacing (**D**). The field research was conducted based on existing guidance where there is barrier overlap (**O**+) of approximately 0.3 m.



Maze layout	W (m)	D (m)	B (m)	O (m)	V (km/h)
TCD Manual	1.7 - 2.2	1.9	2.0 - 2.3	0.3 to 0.5	0* – 12
KiwiRail Maze 1	2.0	2.0	2.3	0.3	0* – 8
KiwiRail Maze 2	2.5	2.5	2.8	0.3	6 – 10
KiwiRail Maze 3	3.0	3.0	3.3	0.3	8 – 12
KiwiRail Maze 4	3.5	3.5	3.8	0.3	10 – 18

Figure 4-1: Observed impact of maze layouts on speed (V) - * means larger cycles could not be ridden through

The tightest geometry mazes (TCD Manual and KiwiRail Maze 1) are unacceptable from a larger bicycle or trike accessibility perspective. KiwiRail Mazes 2 and 3 will likely require some riders to slow below a stable speed. Had the simulation also trialled a barrier end gap of **O**=0, KiwiRail Maze 3 would likely be acceptable except during congested path use times. KiwiRail Maze 4 and larger dimensions (including **O**=0 or negative values) may permit two-way path traffic – at least if one of the opposing direction users is a pedestrian and that person steps aside within the maze.

5 Conclusions

The results indicate that vertical deflection as designed at the test sites is relatively ineffective in significantly reducing path user speed. No real mazes were tested (due to an inability to obtain a permit from KiwiRail in the research timeframes) but the simulations showed that the tighter mazes are unacceptable from an accessibility standpoint. Chicanes have the most effect on speed, but also may prevent legitimate access and create inconvenience. More detail follows on each type of treatment.

5.1 Rumble strips

The research found that rumble strips were not effective in reducing rider speeds. The data show a relatively high standard deviation in recorded speeds (compared with other treatment types), which may indicate a possible unintended consequence of increasing the speed differential between users.

Figure 5-1: Rumble strip detail

The rumble strips in use in Christchurch are approximately 15 mm high and produce an uncomfortable ride for many types of bicycles (especially those with high pressure tyres) and e-scooters. Riders were observed trying to bypass them at rates as high as 60%. This can pose multiple safety risks, such as loss of control or the risk of “wheel overlap”, where the wheels of closely spaced riders travelling in the same direction may collide and cause a crash.

If used on shared paths, they also present a trip hazard for pedestrians.[1]

Flush painted stripes were observed at two sites and these may provide the same results (to alert riders to a hazard) without the discomfort. In other cases, thermoplastic strips with a low (but not flush) profile have been used, generating a similar warning effect. An example of a change in surface colour and texture is shown in Figure 5-2,

Figure 5-2: Texture and colour used to highlight conflict point (S. Kennett)

5.2 Speed humps and platforms

The speed hump and bus stops treatments barely slowed users. However, treatments that caused minor slowing still alert users to a change, and raise their awareness of potential conflicts. Christchurch bus platform ramps have an approach gradient of 1:20, which is relatively comfortable but ineffective at speed management. Some departure ramps (e.g. St. Asaph Street) are twice as steep (1:10). It would appear that reversing these approach and departure ramp profiles would achieve a speed reduction effect, but the researchers suggest that the primary variable affecting speed is the presence of pedestrians and bus patrons.

5.3 Mazes and chicanes

Mazes present the most substantial barrier to access and therefore were a key focus of this research. The dimensions outlined in the KiwiRail guidance for Mazes 3 and 4 permit more accessibility and

[1] The *Pedestrian Network Guidance* specifies 6 mm as the repair intervention threshold for footpath maintenance and 14 mm as a vertical height difference that would cause 50% of pedestrians to trip

manoeuvrability. Tight mazes force riders on larger bikes or with pannier bags to dismount; an inconvenience and barrier to mode shift. When riders are required to slow to around 8 km/h or slower, the rider focuses on manoeuvring and does not look for hazards at the conflict point (i.e. possible approaching trains or oncoming users).

The chicanes studied were effective at reducing path user speed but, at peak path use times, they cause congestion. No path users were observed to be able to navigate a chicane and look for trains or traffic at the same time. The Ilam Road and Winters Road chicanes were placed at least 3.0 m from the roadway junction, which enabled path users some time to check for traffic. The Winters Road chicane had been repeatedly vandalised (one barrier cut), presumably by a frustrated path user.

6 Recommendations

6.1 General recommendations

The recommended treatment depends on policy decisions and/or site-specific aims ranging from raising awareness but maintaining near free flow speeds through to maximal speed reduction while still allowing most riders to maintain stability.

Table 6-1: Recommendations for various treatments

Treatment		Recommendations
Vertical deflection	**Speed hump**	Steep profile speed humps are not recommended because they cause substantial discomfort for riders of cargo bikes, road bikes, e-scooters, and various accessible cycles. Humps that do not continue to the kerb (to maintain stormwater flow) are simply ridden around by familiar riders and hence serve little purpose.
	Platform	Gentle platforms are not effective at reducing speeds but are recommended where required to provide a level surface for pedestrians. Further research is required to determine effective platform ramp gradients.
	Rumble strips	Rumble strips should not be used on pedestrian routes (e.g. shared paths). Lower profile (<10 mm high) rumble strips are ineffective at slowing riders. Higher profile rumble strips are not recommended because they are a hazard and discomfort for riders of road bikes, e-scooters and skateboards. A change in surface texture and colour is recommended instead.
Horizontal deflection	**Maze**	The tightest mazes from KiwiRail (Maze 1) and the TCD Manual are not recommended if the path is to be used by people on bikes. *TCD Manual Part 9* should be updated to reflect that nearly all pedestrian crossings are shared use (i.e., allow bicycles), and should use the values from KiwiRail Mazes 3 and 4, with no overlap between inner barrier ends. The KiwiRail *Ped/Cycle Crossing Guide* should be updated with the findings of this research, particularly that the tightest dimensions (Mazes 1 and 2) are undesirable for cycling and cause instability, dismounting or cause the rider to focus on their front wheel instead of potential conflicts. Paths with high user volumes require more relaxed geometries to minimise conflicts and the need to dismount (to give way to other path users).
	Chicane	If speed management is the objective, a chicane is always preferable to a maze. The barrier longitudinal spacing (**D**) should be 3.0 m and the inner barrier overlap spacing (**O**) should be 0 (i.e., no gap or overlap). If **D** must be reduced or the path has high use, then **O** can be decreased (i.e. some clear gap) – but then the effectiveness at off-peak times is reduced.

Both horizontal & vertical	**Bus stop bypass and speed platform**	These have little impact on speed. Consider if increased awareness is sufficient or if speed reduction is required even when there are no pedestrians present. Steeper ramp gradients may help achieve speed reduction at the risk of causing a greater distraction from the task of looking out for pedestrians and causing riders more physical discomfort. Increased horizontal separation from bus passenger embarkation would be preferable.
	Bollard, rumble strips and curve	Rumble strips should not be used on pedestrian routes. Tight curves and rumble strips in combination are effective at reducing speeds but uncomfortable and may cause loss of control for riders of road bikes, e-scooters and skateboards. Bollards in the paths centre are not recommended and if they are present require proper marking; see the *Access control devices on paths* guidance.

6.2 Chicane recommendations

The following recommendations have been developed through a literature review benchmarked by the field study, first-principles, and turning path analysis. Dimension variables are explained in section 2.3.2.

6.2.1 Barrier features and dimensions

Barriers should have reflective elements for visibility at night. Sight boards if provided will make the barrier obvious from a distance, but should not fully obscure the view into the chicane (e.g., of a small child).

The first barrier encountered (in either direction of travel) should ideally be on the right, bearing in mind that riders will generally be keeping to the left side of the path. This serves two purposes; orienting the rider towards the approaching nearside traffic[2] and providing extra room for a person entering the path to fully exit the road. The chevron arrows should point in the desired chicane negotiation curve.

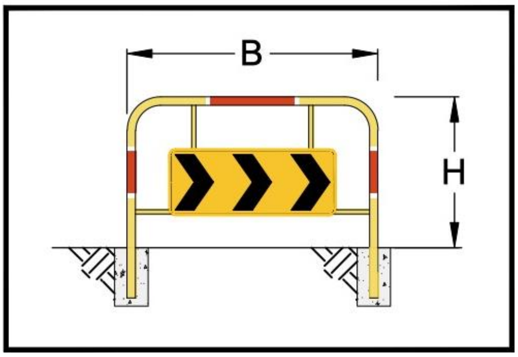


Figure 6-1: Standard U-rail with chevron

The height of the barrier should be between 0.8 m and 1.2 m. To minimise harm to visually impaired pedestrians, provide a tapping rail or bottom of a sight board at least between 0.15 m and 0.2 m from the ground.

Barrier width varies according to the path width, as **O** should ideally be zero at all times. Barriers should be installed at least 0.1 m from the edge of the path. There should not be a gap exceeding 0.6 m around the outside of the chicane, or else the chicane becomes ineffective (a rider can go around it). Providing a gap to the path boundary can minimise the amount of material and cost of barrier installation.

6.2.2 Chicane position relative to the roadway

The minimum distance between the roadway and the nearest barrier should be at least 3.0 m to allow for larger bicycles and prams to fully exit the road if there is a path user already in the chicane. Ideally it would be 3.0 m from the footpath clear zone.

[2] An exception to this is when the road being entered is one-way where riders need to be initially looking left

6.2.3 Barrier overlap (O)

If there is substantial space (**O**-) between the inner ends of the barriers, then the chicane has little practical effect on speed management and may only have a "warning: conflict area ahead" function. The only reasons then for installing such a chicane could be to warn path users or to restrict access. In such cases, consider alternatives to a chicane that are less costly and/or present less inconvenience to path users (e.g. a bollard, red block coloured surfacing, or bands of textured paving).

Overlapping barriers (**O**+) create capacity bottlenecks and may exclude legitimate path users. It is preferable to control geometry through only one variable – the longitudinal barrier spacing depth (**D**).

6.2.4 Barrier spacing (D)

If spacing is constrained by site considerations to less than 3.0 m, then barrier overlap (**O**) might need to be positive. The recommended layout including barrier spacing assumes the ideal barrier overlap (**O**) is zero (no overlap or gap).

The turning path radius (**R**) has been estimated for various barrier longitudinal spacing (**D**), assuming a cyclist envelope of 0.85 m (a typical 750 mm handlebar with 50 mm of shy space either side) and a path that is optimised (apexed). Note that the majority of mobility trikes and bike trailers also have this width dimension, and the few that are wider will still be able to negotiate the chicane without dismounting (but may need to travel slower). These radii are then related to the average speed (through the chicane) for a typical cyclist, determined from a literature review of international guidance (see Appendix A), and benchmarked using field surveys conducted using a standard bicycle and a cargo bicycle. Note that the estimated speed is highly dependent upon a range of factors including competence of the rider and dimensions of the bicycle.

Table 6-2: Speed for typical cyclist based on different spacings of chicane barriers with no overlap (O=0)

Barrier spacing, m (D)	Min. radius of curve, m (R)	Resulting mean speed, km/h (V)
2.5 (absolute minimum)	3.0	9.5
3.0 (desirable minimum)	4.0	11.5
3.5	5.0	13.0
4.0	6.0	14.5
4.5	8.0	16.0
5.0	10.0	18.0

A barrier spacing of 2.0 m results in an inner radius that is slightly less than required for the largest trikes to pass, so if this dimension must be used then some gap should be allowed (**O**-). The desirable minimum barrier spacing of 3.0 m permits the average cyclist to be able to ride through at a speed that is stable (approximately 12 km/h) and to focus on the traffic environment ahead. It also enables the riders of larger cycles to navigate through without dismounting, albeit potentially at a lower speed. Choose larger values of **D** where greater capacity (i.e., two-way path flows) is required. Very busy paths should not have a chicane at all – instead consider treatments such as path markings, bollards, grade separation or traffic signals to manage potential conflicts.

It is assumed that there is *no* situation in which it is desirable to require a cyclist to dismount, as this suggests that larger trikes and trailer bike would be prevented from navigating the chicane at all.

6.2.5 Line markings

White pavement line markings must be provided to guide riders around the fixed barriers. The *Access Control Devices on Paths* guidance (Waka Kotahi NZ Transport Agency, 2020) specifies a 1:20 taper on the approach to the roadway side of the chicane, however this is for higher speed straight alignments. Assuming a barrier width (**B**) of 1.0 m, a taper would need to be 20 m long, and this is in many cases unnecessary. Similarly, a very sharp 1:3 taper provides little advance warning. The ideal taper will depend on the horizontal alignment of the path preceding the chicane and any other approach sight distance considerations. Generally speaking, a 1:8 approach taper should be sufficient.

Figure 6-2 illustrates a recommended layout for a chicane treatment with negligible barrier overlap.

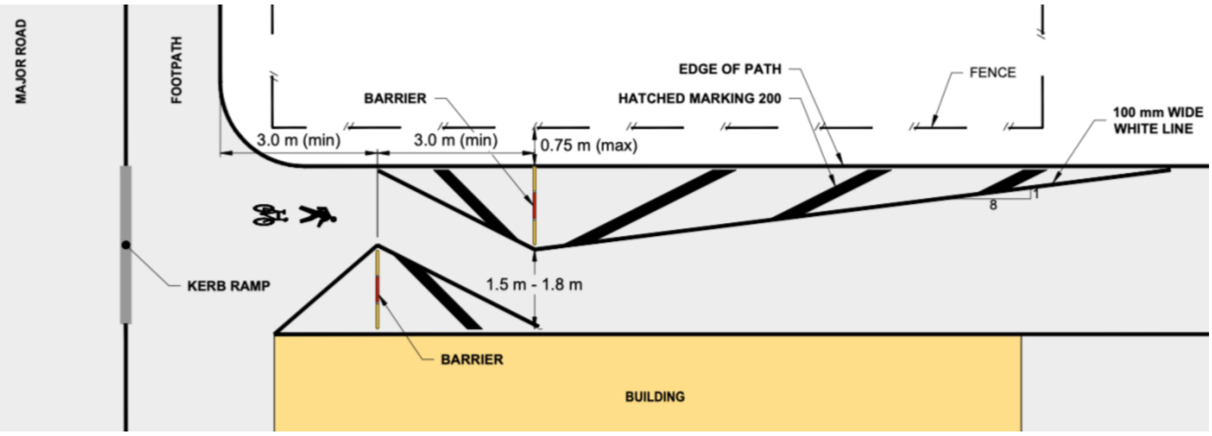


Figure 6-2: Recommended chicane layout where O=0 (no overlap of the inner ends of the barriers)

7 Potential further research

As with any research, our findings have highlighted potential further investigations:

- Include members of the mobility community to assess the impact of speed management devices on pedestrian accessibility.
- Investigate the role of attention in path user safety and how this relates to their safety at these points of conflict, building upon previous work by Stantec for KiwiRail (Stantec, 2018).
- Explore how familiarity can increase speed through devices and how to counteract this.
- CROW (2016) suggests 15 km/h is the speed for moderate cyclist stability (p.47), and 12 km/h is the design speed for the lower limit 5 m curve radius (p.50-51). Our research indicated that many riders of standard bicycles could balance at 6 – 8 km/h (although they could not then focus on potential conflicts); further research could investigate the question of stability and the speed at which rider attention becomes focused on balance and maneouvring.
- Automatic data collection (e.g., video) could also provide insights through conflict analysis.
- There are other international treatments involving vertical deflection (see some examples in Figure 7-1 and Figure 7-2). These could also be trialled in New Zealand, including testing their comfort and effectiveness for a wider range of path users and devices.

Figure 7-1: Asphalt concave multi-speed bump, Houten The Netherlands (image: G. Koorey)

Figure 7-2: Paver concave multi-speed bump, Arkel The Netherlands (image: J.Lieswyn)

References

AASHTO. (2012). *Guide for the Development of Bicycle Facilities, Fourth Edition*. American Association of State Highway Officials. https://bookstore.transportation.org/collection_detail.aspx?ID=116

Auckland Transport. (undated). *Transport Design Manual: Engineering Design Code - Cycling Infrastructure*. https://at.govt.nz/media/1982222/engineering-design-code-cycling-infrastructure_compressed.pdf

Billstein, L., & Svernlöv, C. (2021). *Evaluating the Safety and Performance of Electric Micro-Mobility Vehicles* Chalmers University of Technology]. https://odr.chalmers.se/handle/20.500.12380/303657

CROW. (2016). *Design manual for bicycle traffic*. https://crowplatform.com/product/design-manual-for-bicycle-traffic/

Department for Transport. (2020). *Cycle infrastructure design (LTN 1/20)*. https://www.gov.uk/government/publications/cycle-infrastructure-design-ltn-120

European Cyclists' Federation. (2022). *Geometric design parameters for cycling infrastructure*. https://bicycleinfrastructuremanuals.com/manuals7/ECF-Geometric-Design-Parameters-for-Cycling-Infrastructure-2022.pdf

KiwiRail, & NZ Transport Agency. (2017). *Design Guidance for Pedestrian & Cycle Rail Crossings*. KiwiRail & NZ Transport Agency. https://www.nzta.govt.nz/resources/design-guidance-for-pedestrian-and-cycle-rail-crossings/

MBIE. (2024). *NZ Cycle Trail Design Guide - 6th Edition*. Ministry of Business Innovation and Employment. https://www.nzcycletrail.com/about/nzct-design-guide/

NZ Transport Agency. (2012). *Traffic control devices manual - Part 09: Level crossings*. https://www.nzta.govt.nz/resources/traffic-control-devices-manual/part-09-level-crossings/

Randal, E., Baland, R., & Keall, M. (2018). Children cycling on footpaths. *New Zealand Medical Journal*, *Vol 131 No 1471*. https://journal.nzma.org.nz/journal-articles/children-cycling-on-footpaths

Stantec. (2018). *Distracted Users Survey*. unpublished report for KiwiRail.

Sustrans. (2012). *A Guide to Controlling Access on Paths*. https://www.satinonline.org/Documents/16-a-guide-to-controlling-access-on-paths.pdf

Sustrans. (2019). *Sustrans traffic-free routes and greenways design guide - 9. Access to routes*. https://www.sustrans.org.uk/for-professionals/infrastructure/sustrans-traffic-free-routes-and-greenways-design-guide/sustrans-traffic-free-routes-and-greenways-design-guide-contents/2019-design-guidance/part-2-design-details/9-access-to-routes

Transport for London. (2016). *London Cycling Design Standards Chapter 4: Cycle Lanes and Tracks*. https://content.tfl.gov.uk/lcds-chapter4-cyclelanesandtracks.pdf

Waka Kotahi NZ Transport Agency. (2020). *Access control devices on paths*. https://www.nzta.govt.nz/resources/access-control-devices-on-paths/

Waka Kotahi NZ Transport Agency. (2021a). *Path Behaviour Markings Guidance*. https://www.nzta.govt.nz/assets/resources/path-behaviour-markings/path-behaviour-markings-guidance-note.pdf

Waka Kotahi NZ Transport Agency. (2021b). *Technical Advice Note #21-06 Horizontal geometric design for mobility scooters*. https://nzta.govt.nz/resources/21-06-horizontal-geometric-design-for-mobility-scooters/

Waka Kotahi NZ Transport Agency. (2024). *Accessible cycling infrastructure: design guidance note (draft)*. https://www.nzta.govt.nz/resources/accessible-cycling-infrastructure/

Wheels for Wellbeing. (2020). *A Guide to Inclusive Cycling*. https://wheelsforwellbeing.org.uk/campaigning/guide/

Appendix A Literature review of speed and geometry

Transport standards and guidance from New Zealand, Australia, Europe, Germany and the United States of America provided data points on the speed of cyclists around various curve radii (Table A-1).

Table A-1: Literature included in the review

Author	Year	Title	Link	Radius – speed formula
Austroads, Australia	2021	*Guide to Road Design Part 3: Geometric Design and Part 6A Pedestrian and Cyclist Paths*	Web page	$R = \frac{v^2}{127(e+f)}$ Standard formula used in many guides. Variables are speed, superelevation, friction factor
Agentschap wegen en verkeer, Belgium	2022	*Vademecum fietsvoorzieningen*	PDF	-
AASHTO, USA	2012	*Guide for the Development of Bicycle Facilities (4th Edition).*	PDF	$r = \frac{0.0079 * V^2}{\tan\theta}$ Variables: speed and lean angle. Provided in addition to the standard formula. Use this for low-speed curves.
Baden-Württemberg, Germany	2022	*Qualitätsstandards für Radschnellverbindungen in Baden-Württemberg*	PDF	-
CROW-Fietsberaad, Netherlands	2016	*Design manual for bicycle traffic*	In print only	$R = 0.68v - 3.62$
European Cyclists Federation, Europe	2022	*Geometric design parameters for cycling infrastructure. Summarises all other guides except AASHTO and Austroads.*	PDF	-
Medina and Hernández, Catalonia	2008	*Manual for the design of cycle paths in Catalonia*	PDF	As per standard formula
National Transport Authority, Ireland	2023	*Cycle design manual*	PDF	$R = 0.6v - 3.62$

Generally, the guidance is aimed at facility design to maximise cyclist speeds, increasing the appeal and convenience of cycling. In table form, most of the data points begin at 10 km/h, and some formulae include lean angle. Using the formulae to apply geometry as a means of speed reduction has limited applicability. The tighter turning circles and slower speeds required of cyclists at speed management devices means that variables such as lean angle and friction factor are less relevant. Balance and the minimum turning circle dictated by wheelbase are more relevant.

Speeds in the reviewed literature were most often rounded to the nearest kilometre per hour. Radii of 20 to 25 m was consistently identified as resulting in a design speed of around 30 km/h. In all reviewed literature it is assumed that standard two-wheel bikes were used as the design vehicle.

The European Cyclists' Federation (2022) took multiple European studies on cyclist speeds around radii and graphed each study to compare identified trends (Figure A-1).

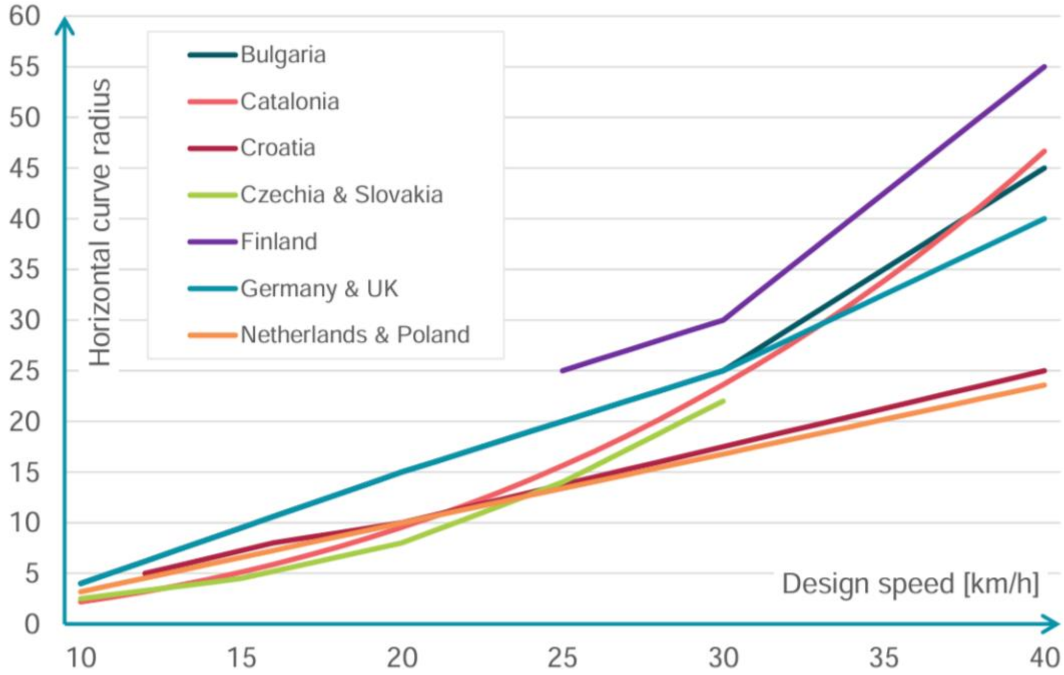


Figure A-1: Comparison of requirements for horizontal curve radii on sealed surfaces in national standards and guidelines (European Cyclists Federation, 2022)

With the addition of Austroads and AASHTO formulae, the relevant speeds and radii found in literature were graphed and a line of best fit plotted. Note that where a formula was provided, design speeds were calculated in 1 or 2 km/h increments at lower speeds (<15 km/h) or 10 km/h increments at higher speeds up to 50 km/h. When combined with the tabular values in the research, over 70 data points provided an r-squared correlation of 0.78.

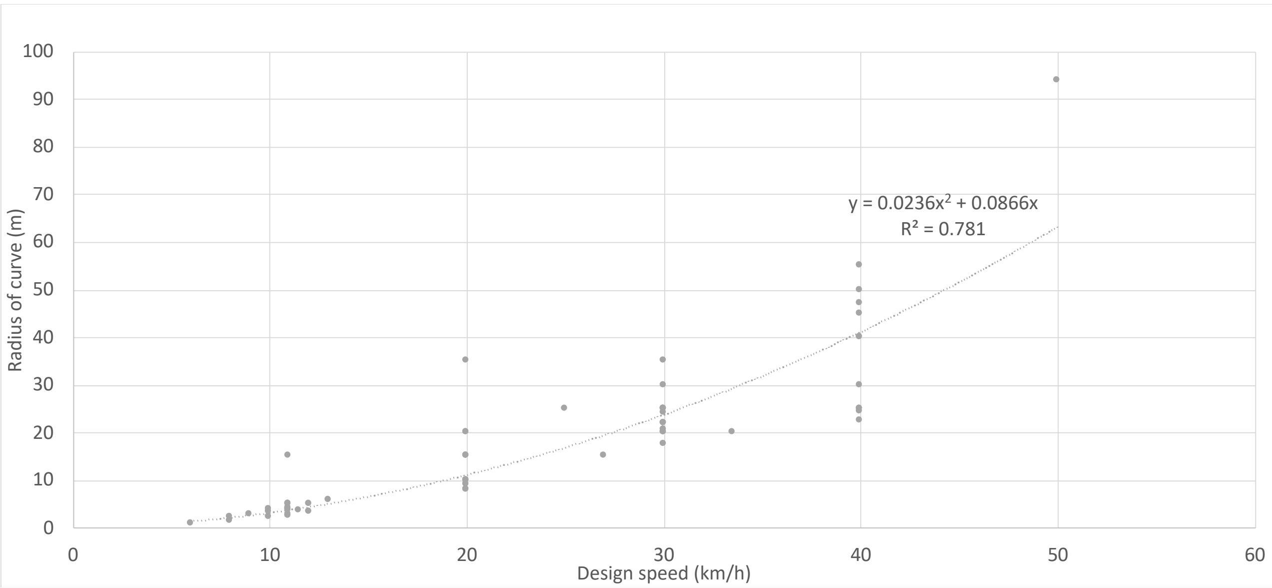


Figure A-2: Scatterplot and polynomial regression line for various speed and curve radii from the literature

The polynomial regression formula $Radius = 0.024v^2 + 0.086v$ was then used to calculate radii that would result in desired speeds (Table A-2).

Table A-2: Cyclist speed and curve radius based on compiled literature – for use in path speed management

Radius (m)	Design speed (km/h)
1.8	7.0
2.0	7.5
2.2	8.0
2.4	8.5
2.7	9.0
3.0	9.5
3.2	10.0
3.5	10.5
3.8	11.0
4.1	11.5
4.4	12.0
4.8	12.5
5.1	13.0
5.5	13.5
5.8	14.0

The green shading indicates the target range for reduced yet still stable speeds (for most riders), and yields a radius of approximately 3.0 to 4.0 m. The values are fairly similar whatever formula or table is consulted.

In addition to the vehicle turning circle and width values (Table 1-1), the literature include the following factors to consider when planning and designing path speed management devices (Table A-3).

Table A-3: Factors to consider in speed management device planning and design

Physical factors

- consequence of hazard
- sight distance and angle to hazard
- warning signage presence or need
- gradient and surface type
- available space for the device / path width

People factors

- path traffic volume
- tidal or stochastic flow
- vulnerability of users
- skill of riders
- path user composition