

# **Factors affecting cycling levels of service**

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All photographs included in this report were taken by the WSP Opus project team, please cite this report for any reuse of these.

## Abbreviations and acronyms

AADT	annual average daily traffic
DCI	dynamic comfort index
CLOS	cycling level of service
CPTED	Crime Prevention Through Environmental Design
LOS	level of service
Transport Agency	New Zealand Transport Agency

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# Executive summary

This study sought to understand how New Zealand cyclists perceive the levels of service (LOS) provided by different types of cycling infrastructure, considering complex external factors (such as motor vehicle traffic, land use, hills and environmental conditions). A further purpose was to provide a user-centred approach to assess existing and proposed facilities that would enable better-informed decisions about target cycling levels of service (CLOS) and key factors to manage in the planning and design of cycle facilities in New Zealand.

The research first took a broad view of how cycling levels of service are currently assessed by a range of New Zealand and overseas methodologies. These approaches have been developed using a mix of methods ranging from survey-based predictive models to expert-driven models. A review of current approaches identified which cycling levels of service elements could influence cyclists' perceptions of infrastructure, and how these perceptions might be measured in New Zealand.

The research used a mixed method approach to record cyclists' perceptions of different cycling infrastructure and cycling level of service elements. First, a group of 63 volunteer cyclists (self-assessed as having at least an intermediate level of cycling experience) rode pre-selected routes in Christchurch, Wellington and Auckland (two routes per city and ~10 riders per route) using instrumented bikes. During these rides the participants stopped at checkpoints to rate the cycling infrastructure and road network environment they had just ridden. Second, video footage from the 'real-time' rides were cut into short video clips and presented in an online survey that was responded to by 1,074 participants, the majority self-assessed as having advanced cycling ability. Participants in the video survey rated their perceived level of comfort with the cycling environment shown across a randomised sample of ~10 video clips from a total sample of 77 videos.

Based on the ratings obtained during the study, and expert input from New Zealand transportation and cycling professionals in workshops, we have proposed evaluation methodologies to assess cycling levels of service for:

- 1 Shared pathways
- 2 Separated cycle lanes
- 3 Painted cycle lanes and sealed shoulders.

These three types of facility were the focus of data collection for the real-time rides and thus obtained the greatest depth of data. Shared roadways, ie different types of general traffic lanes or zones that accommodate cycling, were also cycled for this study but given the diverse range of layouts, traffic conditions and surrounding land use, insufficient data was collected to develop an evaluation methodology for these network segments. Shared roadways, probably the most common type of infrastructure that most cyclists ride, are a gap that should be filled as soon as possible through a study of the most common shared roadway types (neighbourhood greenways, bus lanes, shared spaces and mixed traffic).

Ultimately this research demonstrated some key potential influences on current cyclists' perceptions of cycling infrastructure quality in New Zealand. The research also identified the importance of the interaction between modifiable design elements, such as cycling facility width and separation from traffic, the interactions cyclists have with other network users, and the volume and speeds of motor vehicles, heavy vehicles, pedestrians and fellow cyclists. While these interactions are important, there was not

sufficient data to provide an estimate of the size of these interactions. Further research is needed to better understand their influence.

This study has resulted in a prospective methodology that:

- 1 Integrates cyclists' satisfaction with cycling infrastructure into the expert decision-making process, through the development of user-centred satisfaction distributions of cycling infrastructure that align with the A+ to F grading system used in multi-modal transport planning.
- 2 Identifies important interaction effects between individual CLOS assessment factors, that is, the interactions between infrastructure design elements, eg lane width and non-cyclist modes, eg motor vehicle traffic, as opposed to assessing each variable independently.
- 3 Enables relative comparison of the quality of cycling infrastructure both between different types of cycling facilities, eg separated cycle lanes vs painted cycle lanes, and within types of facilities. This will allow practitioners to better understand the relative benefits of one facility type over another, as well as how different design options for the same facility type can increase or decrease CLOS for a range of typical situations.

This study has used evidence and expert judgement to provide a draft tool as a starting point for better understanding CLOS. It needs further data and development with respect to sample size across all abilities and infrastructure types to complete and refine with practitioners through evaluation of a wide range of bicycle facilities and road network environments around New Zealand. WSP Opus is continuing work with this draft tool and is testing it against several real-world cycling environments. The NZ Transport Agency is also collecting more data and comparing the results with other studies to enable an enhanced evidence-based tool to be completed.

The report also surveyed users about the effect of environmental conditions. The results emphasise the need to take into account weather, amenity and terrain at the route selection and planning stage of cycling infrastructure.

When users of all abilities watched the videos they not only rated the facility on a six-point scale, they also stated whether they would ride there. The results give insight into how good facilities may need to be before cyclists are prepared to use them.

The study revealed many assumptions and gaps in our data and knowledge that should be addressed, particularly in shared roadway environments where there are currently diverse types of road layouts. Intersections remain the most complex aspect of the cycling network to assess. There are a myriad of designs and implementations currently in use with little standardisation. This makes it difficult to apply what we learn from the small number of intersections in this research across the national cycling network.

## Abstract

This report examines cyclists' perceptions of cycle infrastructure levels of service and proposes an assessment methodology for evaluating the level of service provided by cycling facilities.

First, a range of methodologies for evaluation cycling levels of service are described. These are diverse in both their approach and foundations, ranging from tools that are based exclusively upon expert opinion and judgement, to those that rely on user perceptions of infrastructure quality. The latter is an ongoing field of research that seeks to understand what is most important to the cyclists who ride on the infrastructure we build, and to those contemplating doing so.

Second, this study describes a mixed methods approach, using data collected from cyclists (self-assessed as having at least an intermediate level of cycling experience) riding on the road network and participants (the majority self-assessed as having advanced cycling ability) in a video survey to understand perceptions of cycling infrastructure. This information is supplemented by expert opinion from New Zealand transport professionals.

Out of this research, we propose a CLOS evaluation methodology as a starting point for a nationally consistent approach to evaluation of cycle infrastructure in New Zealand. With further work to complete it, the proposed tool will support better decisions, planning and investment for our cycleways by capturing the needs of existing cyclists.



# 1 Introduction

This research sought to understand how different types of cycling infrastructure are perceived by New Zealand cyclists, and how this infrastructure meets their needs in terms of quality, safety and attractiveness. We have used this information to propose a method for rating the cycling level of service (CLOS) provided by different cycling facilities. This approach also aimed to assist in making better-informed and consistent decisions about the design of future facilities, and improvements to existing cycling infrastructure in New Zealand, with regard to key CLOS factors that influence cyclists' satisfaction.

One of the main challenges facing the delivery of cycle infrastructure and facilities in New Zealand and overseas is delivering high-quality infrastructure in highly contested road space that still meets users' needs (recognising that we cannot provide separated/protected cycle infrastructure everywhere). In network planning a framework is used that considers the needs of each mode (freight, cars, public transport, pedestrians and cyclists). The level of service provided for each mode is assessed on a common six-point scale from A to F. These levels of service are compared with a desired or target state to understand the gaps and to develop network operating and improvement plans. Assessment of the main motor vehicle modes is well developed. This study aims to improve the way the needs of cyclists are assessed.

When cycling networks are being planned, multi-criteria analysis is typically used to compare routes and facility types. Cycling level of service is the key consideration. A consistently applied and evidence-based tool would enable better decision making at this important stage of a project. It would also inform the effect of any design compromises being considered due to site constraints.

CLOS evaluation tools are a common approach to assessing the overall, and relative, quality of different facilities along a route. This approach works by 'breaking down' a route segment, normally midblocks or intersections, into a range of individual factors that can each be scored. Planners and designers of cycle infrastructure can then gauge the overall quality of a route segment and see what sub-factors are contributing to a positive or negative CLOS evaluation.

Because CLOS evaluations are generally focused on modifiable infrastructure elements and operating conditions, they generally have a technical perspective and are developed and used by transport sector experts. It is therefore useful to complement the views of engineers and planners with those of cyclists themselves to ensure that evaluations of cycling facilities explain perceptions of comfort among users. This research sought to build on overseas work to provide a New Zealand perspective that is relevant to our local roads, cycling conditions, and cyclist behaviours and preferences.

It is likely that not all CLOS factors are equal in importance to cyclists' perceptions of high quality and attractive cycling environments. By identifying 'key' CLOS factors the research aimed to develop an evaluation methodology that would better explain cyclist comfort and willingness to ride.

In summary, the objectives and scope of the research project were to:

- Analyse the effect of different cycle facilities, infrastructure elements, operating conditions and environmental attributes on cyclist perceptions of CLOS.
- Propose a methodology for including cyclist perceptions in the evaluation of existing and future cycle facilities in New Zealand.
- Present perception ratings of cycle infrastructure and environments collected from cyclists riding on roads and compare these ratings to the perceptions of respondents in an online video-based survey.

- Consider environmental factors likely to influence willingness to ride in different New Zealand contexts.

This report is structured as follows:

- Chapter 2 describes existing approaches to evaluating CLOS in New Zealand and overseas, and introduces methodologies for understanding cyclist perceptions of CLOS and approaches to including these in evaluation methods.
- Chapter 3 outlines the study methodology including research approach and data collection process.
- Chapter 4 presents the study findings for cyclist perceptions of CLOS on different cycling infrastructure types in New Zealand.
- Chapter 5 proposes an assessment framework and rating system for CLOS evaluation of midblock cycling environments in New Zealand.
- Chapter 6 studies the influence of environmental conditions on willingness to ride and cyclists' response to adverse conditions for different trip types and rider experience levels.
- Chapter 7 discusses cyclist perceptions of CLOS based on the current study and makes recommendations for further research.
- Chapter 8 is a list of works consulted during the research.

## 2 Evaluative approaches for CLOS

### 2.1 Common CLOS factors included for assessment

Internationally, many CLOS assessment tools have already been developed, some of which are currently recommended for use in New Zealand. The NZ Transport Agency's cycle network guidance website<sup>1</sup> has a comprehensive review of overseas CLOS assessment tools from a New Zealand perspective (NZ Transport Agency 2017).

Given the high quality and extensive nature of the above review, this research used the Transport Agency's assessment frameworks and description of advantages, disadvantages and recommendations relevant to New Zealand as a starting point for developing a fit-for-purpose New Zealand CLOS assessment tool. Auckland Transport's CLOS assessment tool is also presented as an already established tool in use in New Zealand.

The assessment frameworks are:

- 1 Austroads' level of service metrics (for network operations planning) (Australia)
- 2 Danish cycling level of service (Denmark)
- 3 National Cooperative Highway Research Program (NCHRP) multi-modal analysis (USA)
- 4 Transport for London cycling level of service (United Kingdom)
- 5 Cycling level of service assessment tool (CLOSAT) (Victoria, Australia)
- 6 Bicycle Victoria level of service audit tool (Victoria, Australia)
- 7 Queensland level of service model for bicycle riders (Queensland, Australia)

We also include an eighth approach that was provided to the research team during this study:

- 8 Auckland cycle facility quality of service evaluation tool (Auckland, New Zealand)<sup>2</sup>

See appendix A for an overview of the CLOS factors included in most of the assessment frameworks listed here.

The most common CLOS factors included in each of the above assessment frameworks relate to motor vehicle traffic. This is assessed in terms of traffic volume, traffic speed (posted speed and absolute or relative measured vehicle speed) and the gap between overtaking vehicles and cyclists.

The most prominent CLOS factors relating to cycling facilities (or lack of) are surface quality (smoothness or bumpiness) and the type and width of facilities. A synthesis of common factors included in the assessment frameworks for midblocks is shown in table 2.1.

Not all of these frameworks explicitly deal with intersections, and it is a relatively under-developed area of research compared with midblock sections. Intersections are fundamentally more complex, though we

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<sup>1</sup> [www.nzta.govt.nz/walking-cycling-and-public-transport/cycling/cycling-standards-and-guidance/cycling-network-guidance](http://www.nzta.govt.nz/walking-cycling-and-public-transport/cycling/cycling-standards-and-guidance/cycling-network-guidance)

<sup>2</sup> Available at <https://at.govt.nz/about-us/manuals-guidelines/quality-of-service-evaluation-tool-for-cycle-facilities/#documents>

note that Jensen (2013) has produced some quantitative findings of cyclists' perceptions of satisfaction with different intersection types.

**Table 2.1 Matrix of common CLOS factors across six international approaches to assessing CLOS**

CLOS factor	Austroroads	Danish CLOS	NCHRP	Transport for London	CLOSAT	Bicycle Victoria	Queensland	Auckland Transport	%
Vehicle volume		X	X	X	X		X	X	75%
Vehicle speed		X	X	X	X	X	X	X	88%
Vehicle gap/buffer		X	X	X	X				50%
On street parking		X	X	X	X	X	X	X	75%
Cycle facility type	X	X		X	X	X	X	X	75%
Cycle facility width		X	X	X	X	X		X	75%
Surface quality			X	X	X	X		X	63%
Gradient	X			X		X		X	50%
Adjacent land use	X	X		X					25%

NB Each framework includes more factors than those listed here that are specific to local needs or preferences of those designing the tools. The full list can be found in appendix A.

Across the eight assessment frameworks, there is a mixture of approaches for how individual CLOS factors are assessed by users of the tool. For example, Austroroads' approach is to provide a range of descriptive statements for every factor, the user selects the most appropriate option and a score is provided. While this is easy to use, it is subject to the assessor's interpretation of each factor so the possibility of reproducing the approach is low. Three different assessors may arrive at different scores for the same facility.

Transport for London takes a similar approach, implementing a checklist and rating tool for assessing new projects. Critically, the framework cannot be used to evaluate the adequacy of existing infrastructure as negative features are not scored. Thus, the framework cannot be used to identify poor quality features of existing infrastructure and measure CLOS changes if problems are addressed or changes made to a facility. The London CLOS tool is instead aimed at focusing attention on aspects of a new cycle facility or project that could be improved to attract use by new cyclists.

In contrast, the Danish CLOS and CLOSAT tools require users to enter actual values or select from ordinal ranges based on known/measured values (eg users either enter a known vehicle volume value or select a range for vehicle volume that includes this value). The approach is much less subjective but requires data to be collected to undertake the assessment, or a high degree of confidence in any estimated values that are entered.

Each of the CLOS assessments has been developed using different methods, some are an entirely subjective assessment based on input from planners and/or engineers, while others include subjective measures of user perceptions and seek to incorporate these into a final CLOS rating. There is a growing body of published methods for developing CLOS ratings based on users' experience and perceptions, and using this feedback to validate CLOS frameworks and provide weightings and interaction effects for individual metrics.

A central risk of making use of expert judgement only is that we do not know how sensitive cyclists are to CLOS in practice. Are higher levels of CLOS in the assessment frameworks reflective of increasing levels of satisfaction from riders? Further, it is easy to treat CLOS scoring in a linear fashion, eg A, B, C and D, while cyclists' perceptions of quality may not increase in the same way and it is likely that satisfaction increases in a pronounced manner around certain thresholds. For example, building a non-separated painted cycle lane where there was previously no facility on a busy arterial road may provide some increase in perceived CLOS. However, building a separated cycle lane on the same road will likely provide a much larger increase in perceived CLOS.

A point of difference of the predictive modelling approach used in the Danish CLOS assessment framework is the use of public perceptions and interactions between variables when scoring a cycling facility. Modelling interactions is an important recognition that individual elements of a facility (eg traffic volume, traffic speed, facility width and facility type) are not experienced in isolation by cyclists, therefore a change in one element is likely to influence cyclists' perceptions of other elements.

The Danish CLOS framework demonstrates a robust, perception-based approach to predicting user satisfaction with existing and future cycling facilities. The methodology is relevant for testing in New Zealand; however, given the differences between the two countries' road rules, cycling volumes, road user culture and the amount and design of cycling facilities, specific ratings for New Zealand will need to be established before implementing this approach here.

An expert-driven CLOS assessment framework can therefore benefit from field testing and the inclusion of data collected about cyclists' perceptions of CLOS to validate assumptions. A further benefit is the ability to better identify which individual facility elements contribute most to perceived CLOS, and therefore where we can prioritise investment for improvements if needed.

Auckland Transport's CLOS evaluation tool considers facility types separately:

- separated cycle path – includes bidirectional and unidirectional, can include planted, concrete, or raised dividers/buffers or flexibollards
- shared path – includes any facility that caters to both pedestrians and cyclists
- cycle lane – includes at-grade marked buffered cycle lanes
- mixed traffic – includes on-street greenways, slow neighbourhood streets
- signalised intersection – any intersection with a signal
- unsignalised intersection – T, Y and X unsignalised
- roundabout – any roundabout.

Data input requirements and the scoring system applied vary by facility type. For example, shared paths do not consider the effect of traffic volume or speed so this data is not required, while both cycle lanes and mixed traffic consider traffic conditions but score these differently, eg the lower/worst range for vehicle volume on a mixed traffic segment is >4,000 annual average daily traffic (AADT), while on cycle lanes it is >15,000.

## 2.2 Cyclist perception and acceptance-based CLOS models

How well the design of new and existing cycling facilities meets cyclists' needs and expectations should inform expectations of how many cyclists will be attracted to use them. To date, much of the investment in new cycling facilities, or retrofitting of existing ones, has taken a 'best practice' approach. This has seen planners and engineers designing facilities with an expectation that the finished product will be perceived positively by users, but with little opportunity to validate their assumptions.

The purpose of this research was to better understand how CLOS is perceived from a cyclist's perspective and propose a methodology for evaluating facilities based on what is perceived as good and poor-quality infrastructure. It is impractical to survey potential users of a facility to inform all design elements for each new project, so this work aimed to identify the key factors that explain cyclists' route preferences and willingness to ride. A number of methodologies for capturing this information to inform CLOS assessments already exists, with some previous work carried out in New Zealand by Bezuidenhout et al (2005). This current project aimed to build on previous work to develop a CLOS evaluation methodology that could be practically applied by professionals in the sector.

A range of published methods is described in this section. These methods directly informed the data collection approach employed for the research.

### 2.2.1 Video- and image-based survey data collection

Video-based surveys are a cost-effective approach to collecting user perception data as they have the advantage of being able to engage with many people and can be delivered online to target people from a range of locations.

#### 2.2.1.1 Danish research

The Danish CLOS method made use of video footage from a range of cycle facilities to develop a predictive model of cyclists' CLOS perceptions at intersections and road segments (Jensen 2013; 2007). User perceptions were used to rate cycle facilities, with 407 randomly selected Danes shown video clips from roadway segments and 180 shown videos of intersections, roundabouts and other crossings. This video-based methodology is considered a valid technique for capturing cyclists' perceptions of roadway conditions. Respondents could rate many cycling facility types in a relatively brief time frame, and the video-based approach allowed a large number of diverse people to participate.

Participants replied to the question: 'How satisfied were you as a cyclist on the road shown?', by ticking off a six-point Likert scale ranging from 'very dissatisfied' to 'very satisfied'. No qualitative information was sought and respondents could rate 44 cycling facility types in 56 minutes using this approach. User perceptions based on video footage of cycling facilities were not validated with perceptions of cyclists riding the same routes in real time in this study. To check for consistency a 'learner' video clip was repeated.

For each cycling facility segment videoed, data recorded included:

- weather
- sounds (including non-traffic noise)
- visible signs and markings
- visible objects

- parked vehicles
- pedestrians
- other bicyclists
- motorised mopeds, scooters and motorbikes
- passing motor vehicles (less than 3.5 tonnes and over 3.5 tonnes).

Data was also collected relating to technical design elements of the facility and surrounding environment:

- cross section of the facility, roadway and adjacent paths
- alignment of the facility
- pavement type and quality
- posted speed limits
- road lighting
- driveway frequency and design, plus side roads
- adjacent land use and building types.

This research found that the most important predictors of cyclists' satisfaction were the type and width of the facility, the size of buffer from the facility to traffic in the nearest lane and the distance from pedestrians.

Cyclists were increasingly dissatisfied with rising volumes of traffic on the adjacent road segment and pedestrians in the space, higher numbers of parked vehicles along the route, bus stops interrupting the route and greater vehicle speeds.

A key driver of satisfaction was separation from other road users. Survey respondents preferred facilities where high levels of vehicle traffic were not condensed into the immediately adjacent lane, and those that provided a separate path for pedestrians.

#### **2.2.1.2 Portland CLOS model for protected bicycle lanes**

Foster et al (2015) employed a video-based survey for collecting data on user perceptions, preferring this method over field riders because of its relative efficiency and previous research suggesting comparable results between the two methods.

A range of 20 video clips were presented in 15 minutes, with respondents asked to rate each video on a scale from A (extremely comfortable) to F (extremely uncomfortable). Demographic information was also collected for each participant. A total of 221 individuals participated in this survey process. The study's findings were partially validated by a separate project where cyclists riding on different protected cycle facilities were asked to complete a post-ride survey. The results of the two studies are not directly comparable due to differences in participant recruitment and questions.

The study lists the following protected cycle facility factors with relatively high correlation to comfort scores for which data is likely to be readily available to practitioners:

- buffer type between protected cycle lane and vehicle lanes
- facility type – one-way vs two-way
- motor vehicle speed
- number of motor vehicle travel lanes
- average daily traffic (ADT) as a substitute for number of motor vehicle travel lanes.

### 2.2.1.3 Florida Department of Transport validation of video-based survey data

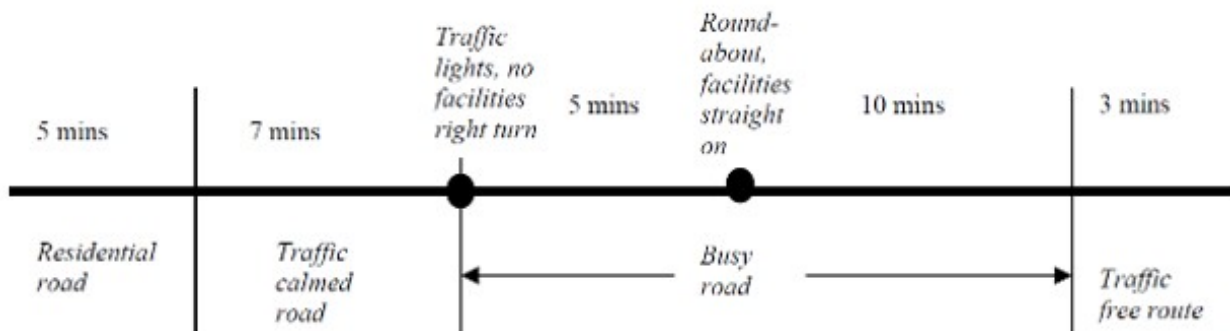
The Florida Department of Transport has previously sought to simulate cyclists' perceptions of riding on a range of facilities (Petritsch et al 2007). Because of concerns about placing study participants in potentially high-risk situations on roadways with high traffic volumes and speeds, and points of conflict, a video simulation methodology was calibrated with field ride data. This study found that cyclist perception data collected from video-based surveys was not statistically different to data collected from cyclists who had ridden the route. A video-based methodology was therefore considered sound for capturing the views of cyclists without placing them in a potentially hazardous situation.

### 2.2.1.4 Bolton United Kingdom perceived risk and acceptability

Parkin et al (2007) present models of cyclists' perceived risk and acceptability for whole journeys using survey responses to video clips of cycle routes and junctions. Video was captured from a moving cycle with 10 route and junction clips being created for the survey of commuter cyclists. The video clips were chosen to represent a range of journeys that a cyclist would typically encounter travelling to work in an urban area.

A novel approach was used to engage participants in the survey process. Each was asked to visualise their home to work journey in terms of a straight line broken up by different route conditions and junctions they encountered (see figure 2.1 below for an example of this). The interviewer then matched video clips to the route sections described by participants for them to review.

Figure 2.1 Example of respondent's home to work journey description (Parkin et al 2007, p.30)



Respondents rated a number of factors for each journey on a 1 (lowest risk) to 10 (highest risk) perceived scale. In total 144 commuters participated in this study rating a total of 873 journeys. Respondents were also asked to cite the point at which their perception of risk became high enough for them to consider it too dangerous to cycle. This point was used to model the acceptability of cycle facilities in terms of risk.

## 2.2.2 Real-time and post-ride surveys

### 2.2.2.1 Christchurch Cycle for Science

Bezuidenhout et al (2005) have published the most comprehensive New Zealand-based CLOS study using survey collected data to date. Participants in this study rated cycle facilities and routes in close to real time, completing surveys at the end of sub-sections of routes as they rode, followed by a post-ride survey on completion of the entire route. This study combined data collected across a range of factors, including:

- demographic variables of study participants
- participants' existing attitudes, local knowledge, cycling competency and experience, and overall attitude toward cycling including their status as an advocate or professional



- experimental conditions such as type of cycle ridden
- physical infrastructure attributes such as type of facility, cycle lane markings, width, traffic volumes and mix of vehicle types, and on-street parking
- other bias variables such as participants' post-survey attitude towards cycling
- perception scores using an overall perception score that may or may not be an aggregate of four sub-perceptions scores of delay, safety, surface condition and attractiveness.

Findings of the Cycle for Science study suggest gender, age and experience have an effect on cyclists' perception of CLOS. Females, young people, mature people and cyclists with less experience were more forgiving in their assessment, tending to give better CLOS scores. In contrast, cyclists with a professional/technical background, such as engineers or members of a cycling advocacy group, were less forgiving and scored lower for the same facilities. This finding is contrary to current expectations which often assume that males and more experienced riders will have more positive perceptions of infrastructure.

Perceptions of vehicle speed, traffic volume and mix of traffic were subjective only. Data was not collected during each participant's ride to quantify their interactions with other road users for comparison with their stated perceptions.

#### **2.2.2.2 Crowthorne, United Kingdom**

Guthrie et al (2001) collected data from the rides of 51 cyclists along a set 9.2 km route made up of 11 individual links of varying types of road and cycling facility. Cyclists rode an instrumented bike which collected information about:

- passing distance of overtaking vehicles (video footage)
- volume of overtaking vehicles (video footage)
- effort rating of cyclist (sensors on chain ring)
- length of each road type link.

The route itself was also surveyed to establish data for:

- widths
- link lengths
- lateral conflicts
- gradient
- average vehicle speeds.

Finally, the perceptions of riders who cycled along the route during the study were captured to compare this subjective data with the instrumented bike and route measurements. Riders scored the following 12 elements of the route on a scale of 1 (poor) to 10 (excellent):

- road width
- traffic flow
- speed of other vehicles on the road (both sides of the carriageway)
- heavy goods vehicles and buses
- gradient

- bumpiness – includes the surface quality at a micro level (texture) and macro level (potholes and speed humps)
- lateral conflict – includes minor road junctions, driveways to more than one premises, bus stops and short or long-term parking
- aesthetics – covers the subjective impression of visual amenity and includes feelings of social safety, surveillance and lighting
- overall feeling of safety
- overall feeling of effort
- overall feeling of pleasure
- cyclability rating (combining all the above).

This study found that 'cyclability' was positively correlated with higher average passing distance, and even more so with higher minimum passing distance. The researchers suggest this provides some evidence that cyclists may be more concerned with the occasional vehicle that passes very close to them than the average passing distance. Cyclability was negatively correlated with high levels of overtaking traffic, increased lane widths, increased effort, increased vehicle speeds, increased gradient, and increases in the number of side turnings per kilometre. The authors cite the negative correlation with increasing lane width as appearing counter intuitive; however, on links with wider lanes there were generally higher traffic volumes, suggesting that individual factors influence each other and are not distinct.

Cyclists' subjective assessment of cyclability on a route was largely determined by their perception of safety, bumpiness and attractiveness. The subjective perceptions of a route could also be partially predicted by measured factors, in particular, vehicle speeds, lane widths, frequency of side turnings and gradient.

### 2.2.3 Instrumented bike data collection

#### 2.2.3.1 Objective vibration measurement

Bil et al (2015) state that cyclists' perceptions of pavement quality are an important predictor of their comfort and subsequent likelihood of selecting a given route to cycle on. They introduce the dynamic comfort index (DCI), a method for objectively describing the vibration properties of surface pavement on a cycle facility.

Data for the DCI is collected by a bike fitted with a GPS device and an accelerometer (MSR1 45s) fitted to the front fork of the bike. The accelerometer had a frequency of 20 Hz, that is, 20 data recordings per second. DCI values are calculated each second and range between 0 and 1, where lower values indicate surfaces with large vibrations and higher values low vibrations.

Cyclists involved in the study were asked to respond to the statement, 'The ride on the bicycle on the given surface was pleasant'. The response options were strongly agree, agree, tend to agree, tend to disagree, disagree and strongly disagree. This study found a significant correlation between the subjective perception of cyclists and the objective DCI measure of surface quality.

#### 2.2.3.2 Canadian naturalistic cycling safety study

Hamann and Peek-Asa (2017) provide a naturalistic study of adult and child cyclist safety-relevant events using video recorded across a full week of usual riding behaviour for each of the 20 participants. The study used a naturalistic methodology as it was considered to be a valid approach to collecting information about cyclists' exposure to behaviours that lead to crashes.

This method differed from the CLOS studies discussed in this report in that it focused specifically on objective measures of safe or unsafe events and behaviours, and did not seek information from the riders about their perceptions of safety on a route.

The use of video footage was shown to be a valid technique for capturing a range of information about real-world events; however, some limitations were cited which generally related to the inability to infer any information beyond what was presented on screen. Therefore, some events could not be coded, such as when legal obligations for road users were not clear or lapses on behalf of the riders failing to check for traffic.

The study authors suggest future studies would benefit from a wider range of instrumentation on the bike and additional camera angles for analysis.

#### **2.2.3.3 Korean categorisation of bicycling environments**

Joo et al (2015) used GPS-based speed data from public bikes to assess the ability of a road segment to accommodate cycle traffic safely and comfortably. This approach attempted to detect and analyse how cyclists respond and interact with the road environment, based on changes in cycle speeds on various road and cycle facility types.

Study participants rode the instrumented bikes twice along two different routes before completing a questionnaire where they rated each cycle environment as being either 'satisfactory' or 'unsatisfactory'. This paper outlines the study methodology for classifying road environments using only the cycle speed data. When compared with cyclists' stated perceptions of the same environments their model could produce a correct classification in 80% of cases.

This methodology of classifying the cycling environment does not account for the wide range of CLOS factors that influence cyclists' perceptions of a facility. However, it provides further validation of the ability to predict subjective measures of cycling facilities using data collected by an instrumented bike.

#### **2.2.3.4 New Zealand instrumented bike data collection methodology**

Hughes (2008) developed a methodology for data collection using an instrumented bike, taking into account the New Zealand cycling context. This project reviewed a number of CLOS assessment methodologies, many of which are included in this report, and proposed a number of factors that might be measured using an appropriately instrumented bike. These factors included:

- traffic flow passing a cyclist
- heavy vehicles passing a cyclist
- parked motor vehicles
- pedestrians (important for shared spaces and roads with no footpaths)
- speed of passing traffic
- road surface roughness and texture
- gradient
- number of through lanes
- type of cycling facility
- number of side roads and driveways
- number of bus stops

- speed profile of cyclist along a route
- cadence and heart rate (measure of effort)
- separation between cyclist and passing motor vehicles, parked cars and pedestrians
- noise
- weather conditions
- GPS location and time
- cyclist wobble
- encounters with other road users.

Many of these variables could be captured from video recording during a bike ride, and factors such as GPS location, vibration from road surface condition, speed of passing traffic and separation to vehicles could be captured from a variety of on-board sensors. The recommendations of Hughes (2008) study were a starting point for the proposed instrumented bike data collection method in section 3.3.2 of this report.

#### **2.2.3.5 New Zealand instrumented bike research application**

In 2016 Opus Research developed two identical instrumented bikes which were ridden by a number of cyclists across the Wellington region to collect data for current cyclist overtaking behaviours exhibited by motorists.

**Figure 2.2 Opus Research's instrumented bicycle**



The instrumented bikes were fitted with sensors that captured the passing distance of vehicles relative to the bike, the absolute and relative speed of vehicles during passing manoeuvres, the location of each passing event on the road network, cyclists 'discomfort' flagged by pressing a button on the handlebars, and video footage of each ride to complement the quantitative data.

Both of these instrumented bikes were applied to this study of cyclists' perceptions of CLOS, see section 3.3.2 for a detailed description of the instrumented bike data collection methodology.

## **2.3 Summary of CLOS methods review**

In conclusion, the key findings for developing the research methodology, and a relevant CLOS evaluation methodology for New Zealand are:

- Motor vehicle factors are most prominent in CLOS assessments, key factors being motor vehicle speed, motor vehicle volume, the overtaking gap from motor vehicles to cyclists, and presence of parked motor vehicles. There are likely interaction effects within motor vehicle factors, and between motor vehicle factors and other design elements such as cycle lane width.
- Cycling facility type and width is important.
- Midblock assessments are more developed than intersection models, with intersections inherently more complex with a much wider range of design options currently in use with varying levels of provision for cyclists.
- Similar assessments draw on a range of data sources, a mixture of cyclist ratings, expert opinion and predictive models in use internationally. No two approaches are the same.

## 3 Research methodology

### 3.1 Research approach

A two-stage research approach was undertaken for this study.

First, six cycle facilities/routes were cycled by members of the public on an instrumented bike (see section 3.3.3). To ensure variation in both route and cycling context, two routes each in Christchurch, Wellington and Auckland were selected. Approximately 10 cyclists were recruited to ride the instrument bike on each route with 63 riders in total (see section 3.3.1). During each ride, participants were asked to stop at pre-selected checkpoints and rate segments of the road network they had just ridden over (see section 3.3.2). This was generally two to three segments broken up into midblock and intersections. In addition to the instrumented bike data collection and personal ratings, each rider was fitted with a chest mounted GoPro camera, which collected video footage of the entire ride.

The second research stage was the use of video footage collected during the real-time rides in an online survey. Videos were clipped to a length of 20–30 seconds showing a rider's trip through a midblock or intersection of interest. This online survey was open to the public and was intended to capture ratings of cycling infrastructure and road network environments from a larger sample than could practically be achieved by the real-time rides alone.

### 3.2 Route selection

The routes were selected to include a range of 'high' and 'medium' priority midblock and intersection segments for the study, these prioritised segments formed the basis for video selection in the online survey and subsequent analysis. The routes and facility types included for each are described in the following sections.

Large versions of the maps included in this section are provided in appendix C. Street names can be read on the larger images.

#### 3.2.1 Christchurch

Christchurch Route 1 is a mostly suburban loop taking in newly built separated cycle lanes on Rutland Street, and older painted cycle lanes on Idris Road and Blighs road. Linking these segments is the shared pathway adjacent to the northern rail line, where our riders cycled the segment between Glandovey and Wairakei roads. Our riders cycled in a clockwise direction on the route shown in figure 3.1.

The separated and painted cycle lanes on this route are all on residential streets, with Idris and Blighs roads classified as level 2 roads with greater than 10,000 vehicles per day (VPD), while Rutland Street is a level 1 road with greater than 5,000 VPD. These classifications are from the One Road Network Classification.

Just one intersection was prioritised for this route, the recently upgraded intersection at Rutland Street and Innes Road which now includes a cyclist phase. Our riders made a straight-through movement at this intersection heading south-east on Rutland Street.

Figure 3.1 Christchurch route 1, cycled clockwise from start point

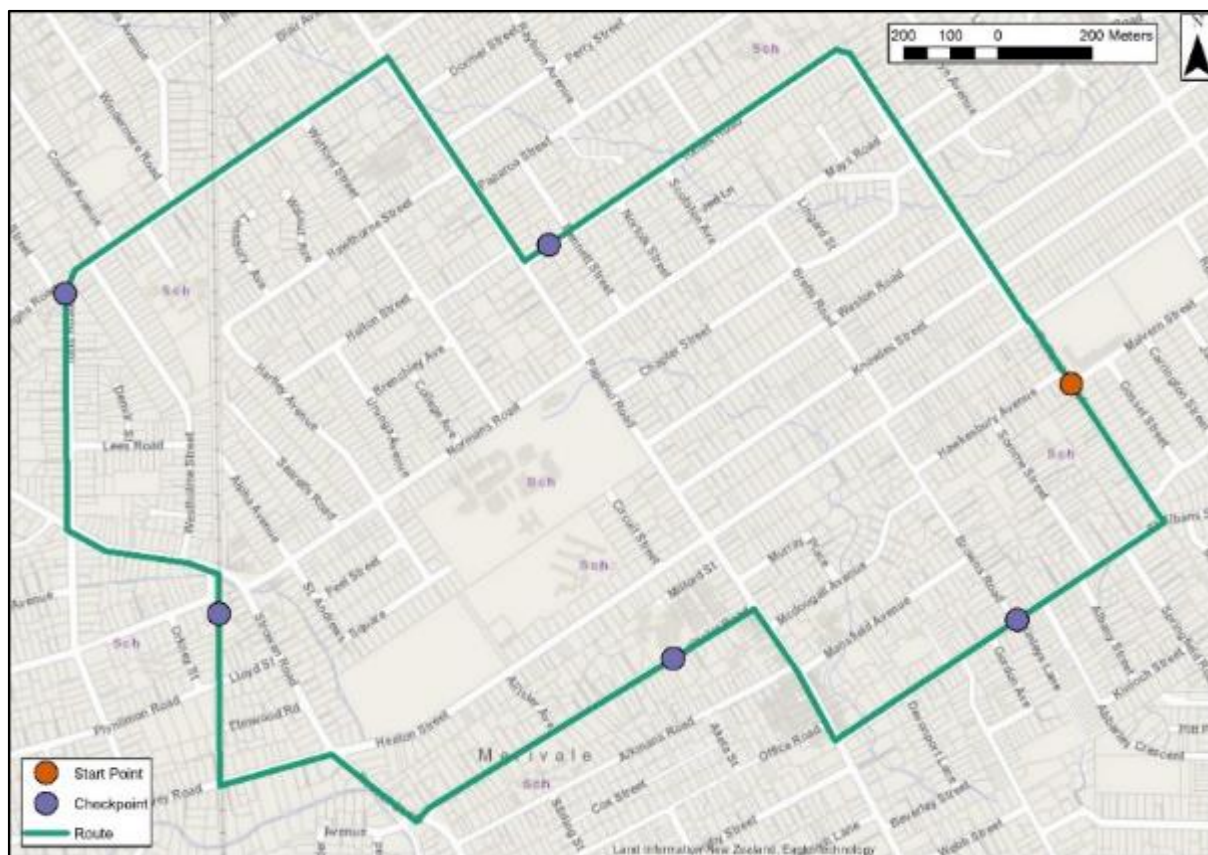
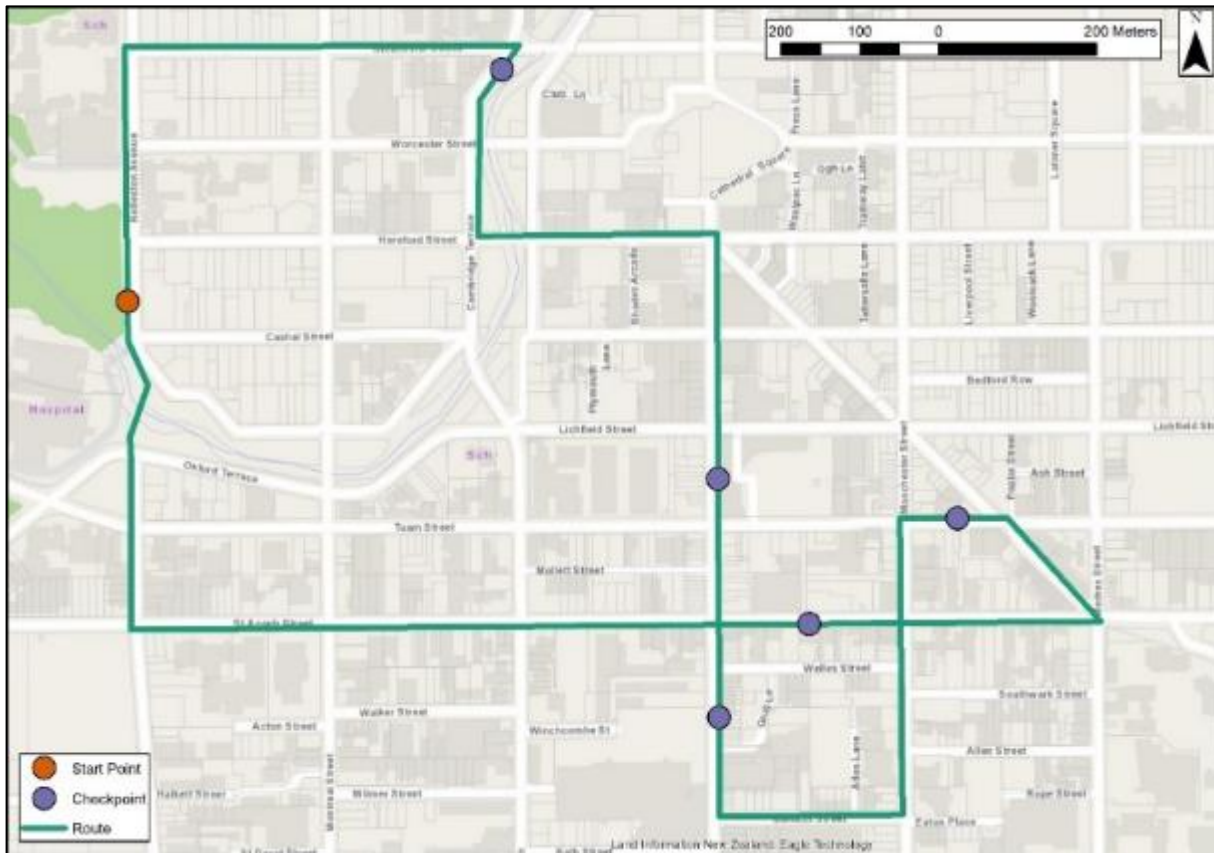


Table 3.1 Prioritised midblock and intersection segments for rating on Christchurch Route 1

Christchurch Route 1 priority rated segments	
Streets	Segment type
Rutland Street (Malvern Street to St Albans Street)	Separated cycle lane
Rutland Street at St Albans Street	Signalised intersection with cycle phase
Papanui Road (Office to Aikmans Road)	Painted cycle lane and mixed traffic
Papanui Road (Aikmans to Leinster Road)	Bus lane
Railway Shared Pathway (Glandovey to Wairakei Road)	Shared pathway
Wairakei Road at Idris Road	Signalised intersection
Idris Road (Wairakei to Blighs Road)	Painted cycle lane
Blighs Road (Idris to Papanui Road)	Painted cycle lane
Blighs Road at Papanui Road	Signalised intersection
Papanui Road (Blighs Road to Tomes Street)	Painted cycle lane
Rutland Street (Tomes Street to Innes Road)	Separated cycle lane
Rutland Street at Innes Road	Signalised intersection with cycle phase

Christchurch Route 2 is a central city route (figure 3.2) that prioritises new separated cycle lanes on Colombo Street (a raised lane to footpath height) and St Asaph Street (low concrete barriers and vehicles parked to the right of the lane). There is also a mix of old and new painted cycle lanes on the two blocks of Manchester Street between Dundas and Tuam Streets.

Figure 3.2 Christchurch Route 2, cycled clockwise from start point



Four intersections were rated on this route, three with cycle phases and one general traffic phase. At the latter our cyclists made a right-turn while all other intersections were straight-through movements.

Table 3.2 Prioritised midblock and intersection segments for rating on Christchurch Route 2

Streets	Segment type
Park Terrace (Gardens entrance to Gloucester Street)	Shared pathway
Hereford Street at Colombo Street	Signalised intersection
Colombo Street at Lichfield Street	Signalised intersection with cycle phase
Colombo Street (Lichfield to Tuam Street)	Separated cycle lane
Colombo Street at Tuam Street	Signalised intersection with cycle phase
Colombo Street (Tuam to St Asaph Street)	Separated cycle lane
Colombo Street at St Asaph Street	Signalised intersection
Manchester Street (Dundas to St Asaph Street)	Painted cycle lane (old)
Manchester Street (St Asaph to Tuam Street)	Painted cycle lane (new)
Manchester Street at Tuam Street	Signalised intersection
St Asaph Street (High to Manchester Street)	Separated cycle lane
St Asaph Street at Manchester Street	Signalised intersection with cycle phase
St Asaph Street (Manchester to Colombo Street)	Separated cycle lane
St Asaph Street at Antigua Street	Signalised intersection
Antigua Bridge across the Avon River	Shared pathway

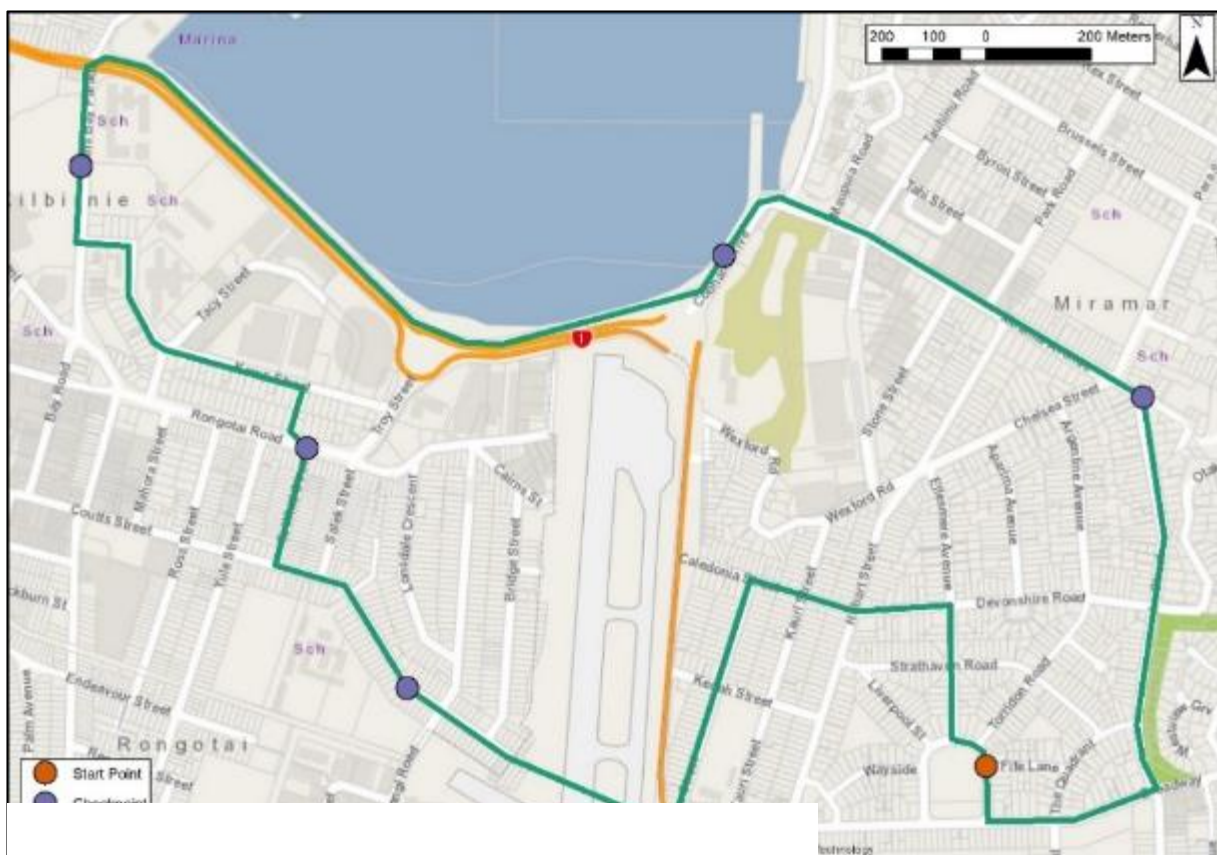


### 3.2.2 Wellington

Wellington Route 1 includes streets in residential, arterial, collector road and suburban centre environments in Kilbirnie and Miramar suburbs (figure 3.3). Several roundabouts were included on this route, though for all but one (Ira Street at Broadway) our cyclists travelled straight ahead and did not make a turn.

On the day of our rides there was a strong northerly wind that our riders were particularly exposed to when cycling on Cobham Drive. This segment was the only on-road section of the study in a 70 km/h speed zone. Cyclists rode on a delineated shoulder, though some chose to cycle the full length on the shared path that is provided to the left of the vehicle lanes.

**Figure 3.3** Wellington Route 1, cycled clockwise from start point



**Table 3.3** Prioritised midblock and intersection segments for rating on Wellington Route 1

Streets	Segment type
Miro Street (Caledonia to Kedah Street)	Mixed traffic
Airport runway underpass	Shared pathway
Coutts Street at Tirangi Road	Roundabout
Coutts Street (Tirangi Road to Te Whiti Street)	Painted cycle lane
Te Whiti Street (Coutts Street to Rongotai Road)	Painted cycle lane
Kemp Street (Troy to Tacy Street)	Shared pathway
Evans Bay Parade at Cobham Drive	Signalised intersection
Cobham Drive (Evans Bay Parade to Troy Street)	Sealed shoulder

Streets	Segment type
Cobham Drive (Troy Street to Calabar Road)	Shared pathway
Miramar Ave at Tauhini Road	Roundabout
Miramar Ave at Park Road	Roundabout
Ira Street (Miramar Ave to The Quadrant)	Sealed shoulder with parking
Ira Street at Broadway	Roundabout with sharrow markings

Wellington Route 2 is a central city route that includes a long section of shared space (excluding motor vehicles) along the waterfront. Our cyclists were exposed to a variety of midblock types including painted and separated cycle lanes, mixed traffic on busy streets and a multi-lane State Highway 1 segment of Vivian Street, and traffic-calmed residential streets on the edge of the city core.

The waterfront sections are unique among the ‘shared pathways’ rated elsewhere in this study. They are very wide, except for the narrow bridge crossings, and on a nice weekend day like when we rode they attract many users across a variety of non-motorised modes. The function of this space is different from that of a shared pathway that connects users from their origin to destination – for many people the waterfront is the destination. Therefore, we would expect the interactions between users and perceptions of CLOS to differ between the waterfront and other shared pathways.

Figure 3.4 Wellington Route 2, cycle anti-clockwise from start point



**Table 3.4** Prioritised midblock and intersection segments for rating on Wellington Route 2

Streets	Segment type
Victoria Street (Wakefield to Manners Street)	Mixed traffic with sharrow markings
Victoria Street at Dixon Street	Signalised intersection
Victoria Street (Dixon to Ghuznee Street)	Painted cycle lane
Victoria Street at Vivian Street	Signalised intersection
Karo Drive (SH1) (Victoria to Cuba Street)	Shared pathway
Karo Drive (SH1) at Cuba Street	Signalised pedestrian and cycle crossing
Karo Drive (SH1) (Cuba to Taranaki Street)	Shared space
Tory Street (War Memorial Park to Vivian Street)	Mixed traffic
Vivian Street (Tory Street to Cambridge Terrace)	Mixed traffic
Pirie Street (Cambridge Terrace to Brougham Street)	Mixed traffic (uphill)
Queen Street (Brougham to Austin Street)	Neighbourhood greenway (uphill)
Elizabeth Street (Austin to Brougham Street)	Neighbourhood greenway (downhill)
Wellington Waterfront Walkway	Shared pathway
Wellington Waterfront Walkway bridges	Shared pathway

### 3.2.3 Auckland

Auckland Route 1 followed a range of cycle facilities alongside major arterials (eg Dominion Road) and suburban commercial centres (along Carlton Gore Road) (figure 3.5). For most of the ride cyclists were on some form of cycle-specific infrastructure such as shared pathway, separated cycle lanes and painted cycle lanes with limited mixed traffic riding. These roads were generally busy with vehicle traffic, and the Northwestern Cycleway segment of shared pathway had a moderate to high number of pedestrian and cyclist users for most of the day.

Figure 3.5 Auckland Route 1, 'out and back' style ride heading north-west from start point first

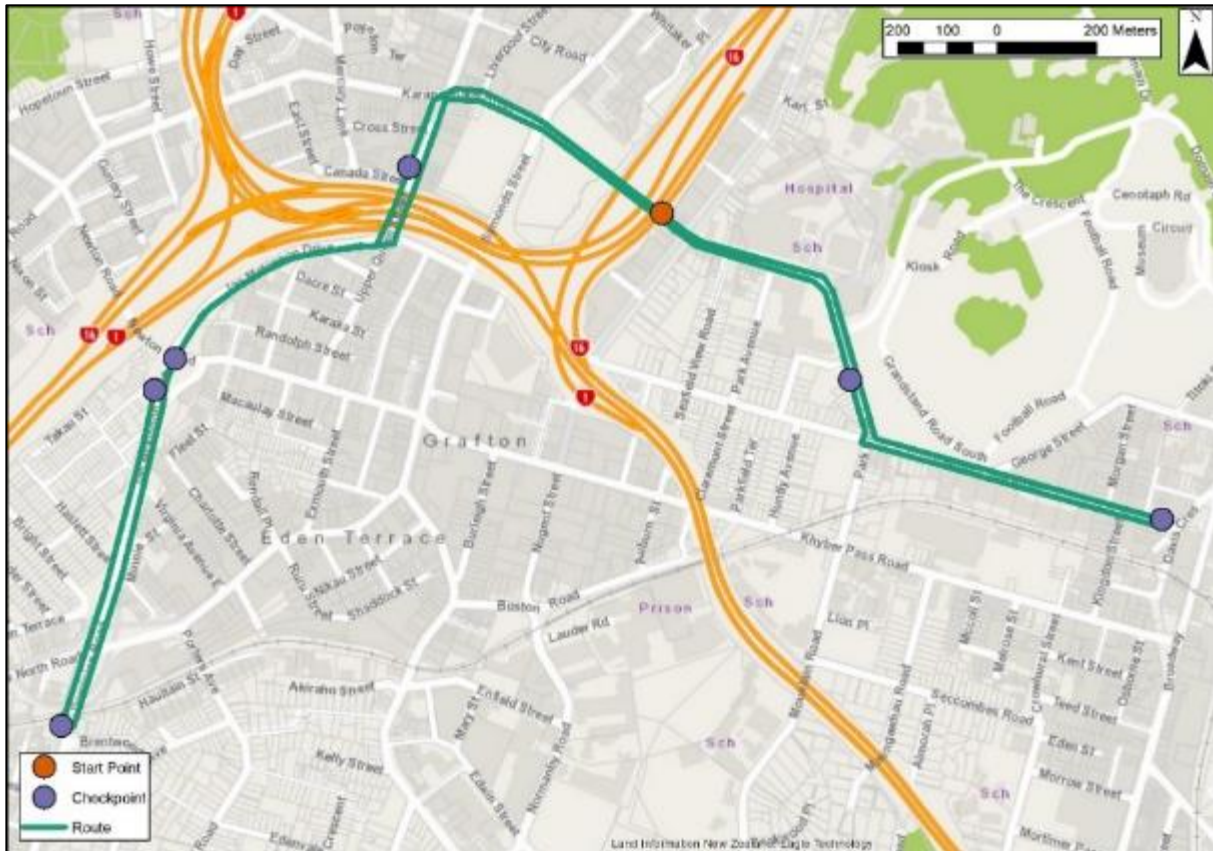


Table 3.5 Prioritised midblock and intersection segments for rating on Auckland Route 1

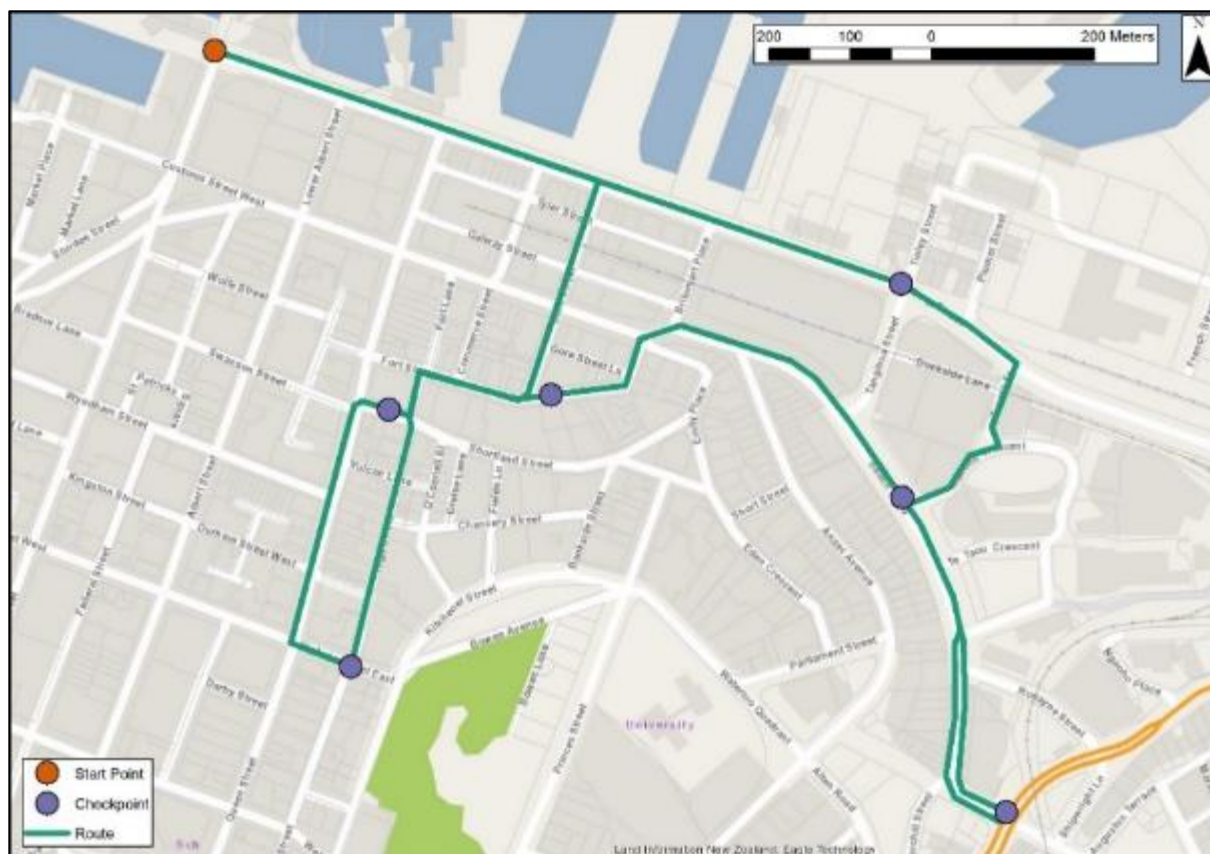
Streets	Segment type
Upper Queen Street (Karangahape Road to Ian McKinnon Drive)	Shared pathway
Upper Queen Street at Ian McKinnon Drive	Signalised pedestrian and cycle crossing
Northwestern Cycleway (Upper Queen to Piwakawaka Street)	Shared pathway (downhill)
Ian McKinnon Drive at Minnie Street	Painted cycle lane across side-road
Ian McKinnon Drive at New North Road Off-ramp	Painted cycle lane across side-road
Dominion Road at New North Road On-ramp	Painted cycle lane across side-road
Dominion Road (northbound between on- and off-ramps)	Shared pathway
Ian McKinnon Drive (Haslet to Devon Street)	Painted cycle lane
Ian McKinnon Drive at Piwakawaka Street	Signalised pedestrian and cycle crossing
Northwestern Cycleway (Piwakawaka to Upper Queen Street)	Shared pathway (uphill)
Ian McKinnon Drive at Upper Queen Street	Signalised pedestrian and cycle crossing
Park Road (Domain Drive to Carlton Gore Road)	Bus lane
Carlton Gore Road (Park to Football Road)	Separated cycle lane (downhill)
Carlton Gore Road (George to Morgan Street)	Painted cycle lane (downhill)
Carlton Gore Road (Morgan to George Street)	Painted cycle lane (uphill)
Carlton Gore Road (Football to Park Road)	Separated cycle lane (uphill)



Auckland Route 2 is a central city route that prioritises separated cycle lanes on Quay Street and Beach Road and includes mixed traffic and bus lanes on inner city streets.

Unfortunately, on the day of the rides an event at the Viaduct Basin prevented our cyclists from riding shared paths and spaces here, as these would be comparable to the Wellington Waterfront sections. The map below shows the shortened route our riders cycled, the viaduct segment is an extension of the Northwestern part of the route.

**Figure 3.6** Auckland Route 2, cycled clockwise from start point



**Table 3.6** Prioritised midblock and intersection segments for rating on Auckland Route 2

Auckland Route 2 priority rated segments	
Streets	Segment type
Quay Street (Hobson Street to Ferry Terminal)	Separated cycle lane
Quay Street at entrance to Captain Cook Wharf	Painted cycle lane across side road
Beach Road (Tangihua Street to Te Taou Crescent)	Separated cycle lane
Beach Road at Te Taou Crescent	Signalised intersection with cycle phase
Beach Road at Te Taou Crescent	Signalised intersection with cycle phase (Barnes Dance)
Beach Road (Tangihua to Fort Street)	Cycle path
Fort Street (Beach Road to Jean Batten Place)	Shared space
High Street (Shortland Street to Victoria Street East)	Mixed traffic
Victoria Street East at Queen Street	Signalised intersection

Auckland Route 2 priority rated segments	
Streets	Segment type
Queen Street (Victoria Street East to Shortland Street)	Bus lane
Queen Street at Shortland Street	Signalised intersection
Gore Street at Quay Street	Signalised intersection
Quay Street (Gore Street to Ferry Terminal)	Separated cycle lane

## 3.3 Data collection

### 3.3.1 Real-time study participants

Recruitment of cyclists to ride an instrumented bike for field data collection was undertaken using WSP Opus Research's register of interested study participants for cycling studies. For health and safety reasons, only cyclists with a rated ability of at least 'intermediate' were selected for the study, with the majority rated as 'advanced' or 'expert'. While this excluded perceptions from non- or beginner riders during the on-road rides, it was deemed an acceptable trade-off to ensure our riders had a strong level of confidence and experience riding on unfamiliar roads.

Cyclists were categorised into one of four groups based on their existing experience and attitudes towards bicycling. The names for these categories vary internationally but are generally consistent with the classification presented in table 3.7. These criteria were originally developed for New Zealand cycling research by Opus (Balanovic et al 2016) and have been reused for this study. Cyclists are allocated a rating for their ability based on their responses to a series of survey questions.

The most popular international description of these categories comes from Portland (Geller 2006). His categories were 'strong and fearless', 'enthused and confident', 'interested but concerned', 'no way no how'. The first three roughly correspond to expert, advanced and intermediate categories in this study. Those who were not contemplating cycling, were not asked to rate any sites.

Most improvements to cycling infrastructure aim to attract the 'interested but concerned' or 'intermediate' group so it was important to have this group well represented in the study participants.

**Table 3.7** Criteria for cyclist ability/experience rating

	Self-rated cycling ability	How frequently have you cycled in the past 12 months?	How do you describe yourself as a cyclist?	How would you describe your riding style?	How much cycling have you done as an adult?
<b>Beginner</b>	Beginner	Not at all/ occasionally	Timid/ cautious	Avoidant/ defensive	Hardly any/ a little
<b>Intermediate</b>	Intermediate	Occasionally/ sometimes	Cautious	Defensive/ Middling	A little/some/ quite a bit
<b>Advanced</b>	Advanced	Regularly/often	Confident but cautious	Middling/ assertive	Some/quite a bit /a lot
<b>Expert</b>	Expert	Often/frequently	Quite confident/ confident	Middling/assertive/ aggressive	Some/quite a bit/a lot

Along with the cycling ability of participants in this study there were several demographic and personal background factors of interest:

- age
- gender
- the purpose of cycling trips, eg recreation, commuting, shopping
- role as a cycling advocate or connection to cycling advocacy group(s)
- technical background in a related field, eg transport planning, engineering, urban design, policy.

A total of 63 riders took part in the on-road component of this study, 20 in Wellington, 23 in Auckland and 20 in Christchurch.

Many more males than females were recruited to ride for this study. Overall, the response rate from women who registered interest in the study was low and some were unable to ride on the proposed dates or times. Effort was made to increase the number of female riders, but with little success. This was a limitation of the real-time ride dataset collected for this study.

**Table 3.8 Breakdown of cyclists by gender and city**

<b>Wellington</b>			
	Female	Male	Total
Intermediate	1	6	7
Advanced	1	7	8
Expert	1	4	5
Total	3 (15%)	17 (85%)	20
<b>Auckland</b>			
	Female	Male	Total
Intermediate	3	3	6
Advanced	2	6	8
Expert	3	6	9
Total	8 (35%)	15 (65%)	23
<b>Christchurch</b>			
	Female	Male	Total
Intermediate	1	3	4
Advanced	2	7	9
Expert	3	4	7
Total	6 (30%)	14 (70%)	20
<b>Total study</b>			
	Female	Male	Total
Intermediate	5	12	17
Advanced	5	20	25
Expert	7	14	21
Total	17 (27%)	46 (73%)	63

### 3.3.2 Real-time ratings

During the on-road rides, riders were asked to rate segments across a range of factors. By segment type these were:

#### Midblock on-road

Overall perception  
Traffic safety  
Space/width  
Surface quality  
Attractiveness/amenity

#### Midblock off-road

Overall perception  
Attractiveness/amenity  
Space/width available  
Surface quality  
Other user conflicts

#### Intersections

Overall perception  
Traffic safety  
Cyclist safety/priority features  
Surface quality  
Delay experience

Each rider rated these factors on a 6-point scale that ranged from -3 to +3, from very poor to very good with intermediate points not described. For clarity during analysis and reporting or mean ratings the scale was transformed into a 1–6 scale. Riders also had the opportunity to provide comments alongside individual ratings where they added context. Each rating sheet included images of the midblock or intersections of interest as a prompt, although riders were asked to rate based on their own experience on the day. An example rating sheet looks like:


Figure 3.7 Real-time ride rating sheet example

**Section 2 Questions:**

Have you ridden this section before?	Never	Occasionally	Frequently
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**Victoria Street cycle lane (painted section)**

Overall Perception	Very poor -3	-2	-1	+1	+2	Very good +3	Comments
Traffic Safety	Very dangerous -3	-2	-1	+1	+2	Very safe +3	Comments
Attractiveness	Very unpleasant -3	-2	-1	+1	+2	Very pleasant +3	Comments
Surface Quality	Very poor -3	-2	-1	+1	+2	Very good +3	Comments
Space/width available	Very inadequate -3	-2	-1	+1	+2	Very adequate +3	Comments



**Victoria Street and Vivian Street Intersection**

Overall Perception	Very poor -3	-2	-1	+1	+2	Very good +3	Comments
Traffic Safety	Very dangerous -3	-2	-1	+1	+2	Very safe +3	Comments
Cycling provisions (e.g. markings, lights, separation)	Very unpleasant -3	-2	-1	+1	+2	Very pleasant +3	Comments
Surface Quality	Very poor -3	-2	-1	+1	+2	Very good +3	Comments
Delay	Extreme delay -3	-2	-1	+1	+2	No delay +3	Comments





### 3.3.3 Instrumented bike data collection

Opus' instrumented bikes collect data via a range of on-board sensors that are complemented by synchronised video footage for manual processing of wider factors in a cyclist's environment. This system comprises three sensor and processing modules (figure 3.8):

- 1 Front module: light detection and ranging (LiDAR) unit and wide-angle video camera (for this study a chest mounted GoPro camera was used for video recording)
- 2 Rear module: LiDAR unit and GPS
- 3 Central module: accelerometer, data processor and storage, power pack.

**Figure 3.8** Front and rear mounted sensor modules (LiDAR, GPS, accelerometers and wide-angle video) on Opus Research's instrumented bicycle



For this study these sensors were used to capture quantitative data for:

- GPS location, this is continuously recorded so that an event (eg overtaking vehicle capture) can be attributed to a specific location, while the route itself can be mapped and overlaid onto network and topographic maps as needed. Synchronised time stamps can be used to identify the exact location of interactions and points of interest identified on the video capture.
- Speed of the bike, via a wheel mounted speedometer calibrated against the wheel diameter for a precise measurement of speed throughout the ride. This data is also necessary for calculating absolute and relative vehicle passing speeds as captures are being made from a moving platform.
- A count of passing vehicles, their speed and the distance the vehicle is to the right of the cyclist and bike. Front and rear mounted LiDAR units capture vehicle passing speeds. This system is 'triggered' by the rear unit as a vehicle begins to overtake, with the time taken to travel between the two LiDARs, and the average measured distance from both units used to determine precise measurements for analysis. Vehicles can be categorised by length to estimate the percentage of heavy and light vehicles passing the bike.
- Road surface conditions via accelerometers that will be used to infer road surface roughness/texture where possible. An accelerometer mounted on the bike captures movements on the x, y and z axes – this information can be used to infer relative road surface roughness.

To complement this information high quality video footage from a chest mounted GoPro camera was captured throughout each ride, this footage was evaluated by the research team to identify environmental and network conditions including:

- presence and number of parked cars to the left and right of the cyclist along the route
- the number of overtaking and oncoming vehicles (all traffic and heavy) passing the rider (complementing the auto-capture of vehicles by length from the LiDAR instruments)
- pedestrian counts on shared paths
- interactions with other road users – pedestrians, cyclists and motor vehicle drivers.

### 3.3.4 Online survey data collection

Video footage captured via the chest mounted GoPro during the on-road ride component of the study was used in an online survey sent out to the public. The chest mounted camera was positioned to roughly simulate what a cyclist would see, while being more stable than a helmet mounted camera. In the videos the rider's hands and the bike's handlebars could be seen as well as the road environment in front (figure 3.9).

Please see appendix B for a high-level summary of the video clips.

**Figure 3.9** Screen shot of video footage from online survey (Quay Street two-way separated cycle lane)



A total of 1,074 individuals completed the online survey, these people were primarily recruited via: Wellington City Council's Resident Survey Panel, Opus Research's Survey Participant contact list, and through word of mouth from cycle advocacy groups and participants themselves.

The online survey consisted of three main sections:

- 1 Participant demographics and cycling experience. These questions aimed to capture background information about individuals, their current cycling frequency, stated ability and confidence levels, and their connection with cycle advocacy or professional transport interest groups/employment.
  - a Participants who stated they did not currently ride and had no intention of riding in the future even if cycling conditions were improved were screened out of the survey. All other participants were retained including those who had not cycled for some time, or had never cycled before, but believe they would cycle in the future if conditions improve.

By source this resulted in completion rates of: Wellington City Council panel: 366/870 – 42%; WSP Opus list: 520/540 – 96%; other sources: 188/210 – 90%. The relatively low rate for the council panel was not unexpected. These individuals were sent the survey while having no potential interest in cycling. Further, we note that the use of a resident survey panel only in Wellington may have introduced some biases to the data collected from this group. In contrast, participants via the Opus list or who had visited the survey after seeing a different form of marketing had made a conscious decision to participate in cycling research and so were more likely to be a current rider.

- 2 Environmental level of service questions. These questions aimed to capture participants' perceptions of the effect of environmental conditions such as hills, wind, rain, flooding, sea spray and wave inundation. We asked participants how these conditions impacted on their willingness to ride for different trips, and if/how these conditions should be mitigated for.
- 3 Ratings of different New Zealand cycle environments. Video footage captured during the on-road section of the study was cut into 77 short (20–30 second) video clips. Participants in the study were

each assigned a random block of 11 videos. This survey structure meant that each video was rated roughly 150 times by our survey group. For each video, participants responded to two questions:

- a 'As a cyclist, how comfortable would you feel riding here?'

Six-point Likert scale response options: very uncomfortable, uncomfortable, slightly uncomfortable, slightly comfortable, comfortable, very comfortable.

- b 'Would you cycle here?'

Yes/No response.

The combination of these two questions was used to identify participants' relative level of comfort with a facility, and their stated willingness to ride on a facility. The second question was used to identify infrastructure where cyclists have a given level of being 'uncomfortable' but would still cycle there suggesting that the discomfort is not enough to prevent a trip being made, but that there is room to improve the provision of infrastructure.

Table 3.9 presents the demographic breakdown of the video survey sample. Note the small number of beginner riders included in the study, a number of participants were screened out of the survey who stated that they have no future intention to cycle even if infrastructure is improved. This group would otherwise have been considered as beginner riders but their lack of intent to ride precluded their involvement. This small group of beginner riders rated 144 different videos between them so we do present results from this group but their trends should be interpreted with caution.

We had hoped for higher participation of beginner riders, particularly through the Wellington City Council resident's panel. It is likely that there is an element of self-selection here, with members of that panel who are current cyclists more likely to participate than those who do not or have very limited cycling experience. Incentives were offered in the form of randomised prizes for participation to try to encourage a more diverse range of respondents.

**Table 3.9 Online survey participant demographics**

Strata	Count	Proportion of total
Female	423	39%
Male	651	61%
Beginner	13	1%
Intermediate	275	26%
Advanced	486	45%
Expert	300	28%
34 years and under	203	19%
35 to 54 years	583	54%
55 years and above	288	27%

## 4 Perceptions of cycling levels of service

This chapter presents statistics from the real-time and video survey components of this study. For all graphs and tables where the ordinal scale 1–6 is used, 1 reflects the ‘worst’ or ‘most uncomfortable’ rating point, and 6 is the ‘best’ or ‘most comfortable’.

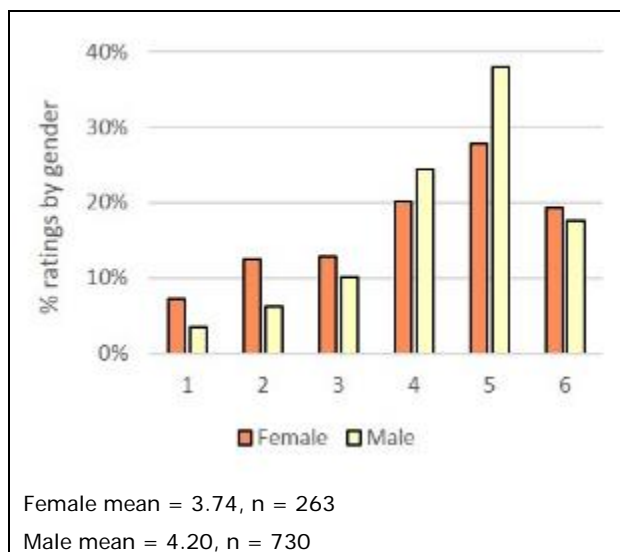
### 4.1 Survey perception ratings

#### 4.1.1 Participant demographics

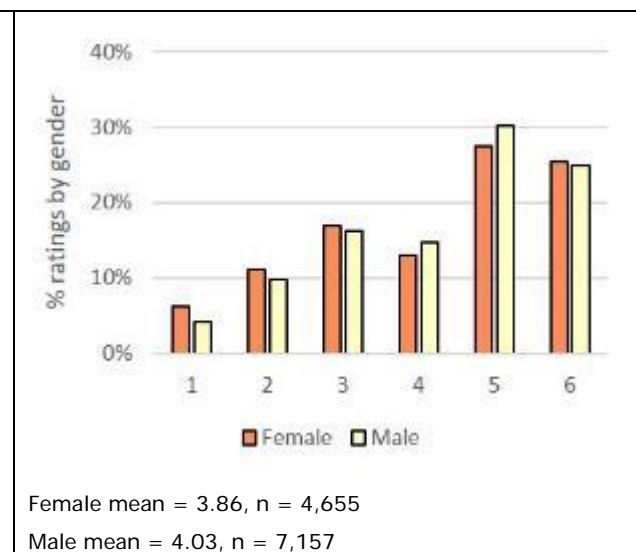
Males rated facilities more positively than females during both the real-time rides and video survey responses, though the mean perception was lower among females and higher among males for the real-time compared with the video survey ratings (figures 4.1 and 4.2).<sup>3</sup>

This contrasts with the findings of the 2005 Cycle for Science study where females’ overall perception scores were significantly higher compared to males. The real-time ride component of this study comprised relatively few females to males (17 vs 46 respectively), though Cycle for Science also had fewer females (55 vs 113 respectively). The spread of females across the three cities may also have influenced this; however, it is worth noting that Auckland and Christchurch, where most of our female riders rode, received higher overall perception scores compared with Wellington (see section 4.1.2).

**Figure 4.1** Distribution of overall perception ratings by gender for real-time rides



**Figure 4.2** Distribution of overall comfort ratings by gender for video survey



Willingness to ride varied slightly by gender across the study sample, with males more likely to have stated no when asked about their willingness to ride based on the cycling scenarios depicted in the video survey:

<sup>3</sup> Please note that mean ratings of ordinal data should not be used to make interval comparisons between groups, eg to state that one factor is ‘1 point higher than another’, rather we can state that the ‘mean rating for x is higher than y’.

**Table 4.1** Yes/No willingness to ride statistics by gender for video survey

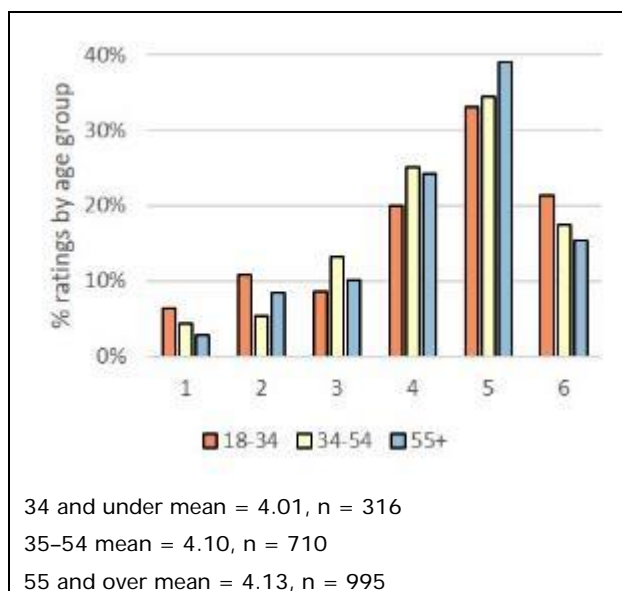
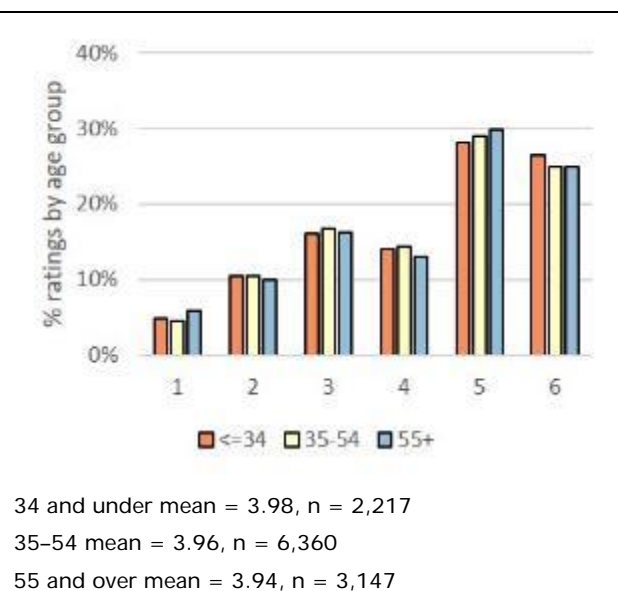
	No	Yes
Female	12.2% (535)	87.8% (3,861)
Male	8.7% (560)	91.3% (5,899)

The distribution of ratings by broad age group differed between real-time rides and video survey responses (figures 4.3 and 4.4). Real-time ride ratings had a pronounced 'peak' around 5 on the 6-point scale, while the video survey ratings had a similar peak but a slightly fatter tail, towards the negative end of the scale. The mean ratings for all age groups were therefore higher for the real-time rides compared with the video survey responses. However, it is worth noting that for all age groups a similar percentage of highly positive ratings in the upper two categories (5 and 6) were given:

**Table 4.2** 'Highly positive' combined ratings as a percentage of total ratings by age group and survey group

	Real-time ratings	Video survey ratings
34 and under	54.3%	54.7%
35 – 54	52.0%	54.0%
55 and over	54.4%	54.9%

The most notable difference between the real-time and video survey responses was the change of direction across age groups. For the real-time rides average perceptions improved with age, while the opposite was found for the video survey rides, and the range across groups was narrower. There was likely an effect of experience at play here, older riders in the real-time rides tended to be more experienced and beginner riders were excluded completely.

**Figure 4.3** Distribution of overall perception ratings by age group for real-time rides**Figure 4.4** Distribution of overall comfort ratings by age group for video survey

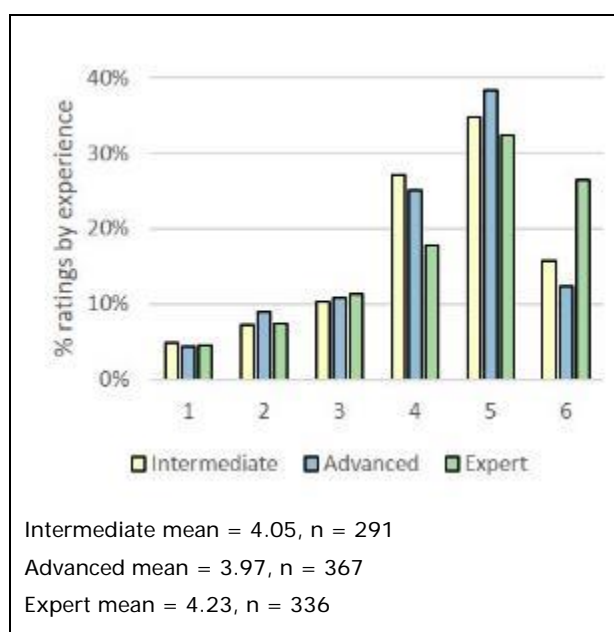
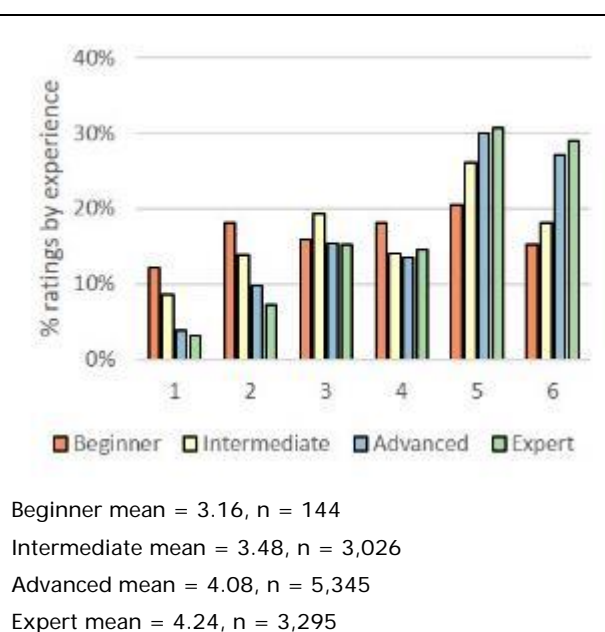
Age had a slight effect on willingness to ride among video survey participants, with an increase seen among the older 54 and above age group compared with younger participants:

**Table 4.3** Yes/No willingness to ride statistics by age group for video survey

Age group	No	Yes
34 and under	9.9% (198)	90.1% (1,802)
35 to 54	9.3% (558)	90.7% (5,469)
55 and above	11.5% (333)	88.5% (2,554)

In both the real-time and video surveys expert riders rated facilities more positively compared with less experienced cyclists. During the real-time rides intermediate riders rated facilities more favourably than advanced riders, with a higher proportion represented in each of the top three categories (figure 4.5).

In contrast, there was a more pronounced increase in ratings with cyclist experience levels from the video survey (figure 4.6). Beginner rider ratings were more evenly distributed across the six categories with much less of a pronounced peak at the upper end as seen across the other experience levels here. Intermediate cyclists in the video survey on average rated facilities lower than their counterparts in the real-time rides, while advanced riders rated slightly more positively.

**Figure 4.5** Distribution of overall perception ratings by cycling experience level for real-time rides**Figure 4.6** Distribution of overall comfort ratings by cycling experience level for video survey

A relatively large variation in willingness to ride is seen by level of experience. More experienced riders have a substantially lower proportion of 'unwillingness' to ride based on the cycling scenarios depicted in the video survey compared to less experienced riders. This suggests about one in three beginners, but also about one in five intermediate riders are unable to ride on parts of the existing cycle network due to a lack of safe infrastructure.

**Table 4.4** Yes/No willingness to ride statistics by rider experience for video survey

Experience	No	Yes
Beginner	32.6% (43)	67.4% (89)
Intermediate	19.6% (541)	80.4% (2,221)
Advanced	7.0% (353)	93.0% (4,688)
Expert	5.6% (172)	94.4% (2,893)

In addition to experience level, participants in the video survey were asked about their formal, volunteer and informal experience in cycling advocacy, technical professional and organised cycle group roles. The number of individuals who cited these connections were:

- 266 who were a member of an organised cycle club or group
- 150 who were an official cycling advocate, or had connections to a cycling advocacy group
- 107 who had a technical background in a related field (eg transport planning, engineering, urban design or policy).

Of this group some individuals stated they had experience in more than one of these roles:

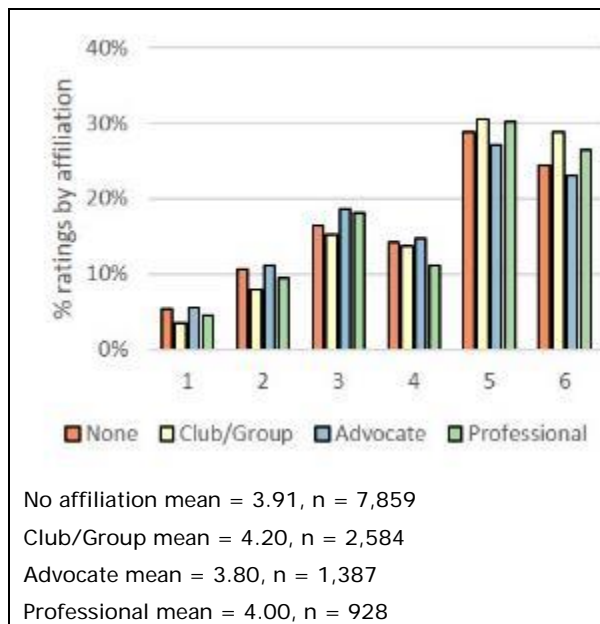
- 42 were both a member of an organised cycle club or group, and an official cycling advocate, or had connections to a cycling advocacy group
- 19 were both a member of an organised cycle club or group and had a technical background in a related field
- 16 were both an official cycling advocate, or had connections to a cycling advocacy group, and had a technical background in a related field.
- nine played a role across all three interest groups.

The previous Cycle for Science study in 2005 found slightly increased perceptions among participants with a technical background compared with those who did not have this. This study found a similar trend, except for individuals who were affiliated with a cycle advocacy group or were an official advocate themselves. This group on average rated facilities lower than all other groups including those who had no stated affiliation.

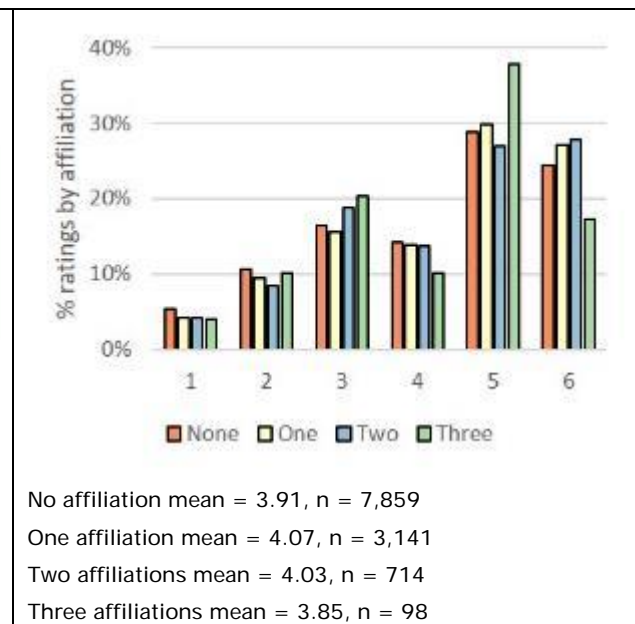
Members of cycle clubs or groups on average rated the highest followed by those who had a cycling-related technical background. There was a slight effect of the number of affiliations on overall perceptions of comfort, with individuals who had one or two stated affiliations rating slightly higher compared with those who had no affiliation. Individuals who selected all three options rated the lowest on average, though the sample size for this was just nine.



**Figure 4.7** Distribution of overall comfort ratings by type of cycling affiliations for video survey



**Figure 4.8** Distribution of overall comfort ratings by number of cycling affiliations for video survey



A somewhat similar trend is seen for willingness-to-ride statistics, with individuals who had an affiliation citing a willingness to ride with a higher prevalence compared with individuals who had no affiliation:

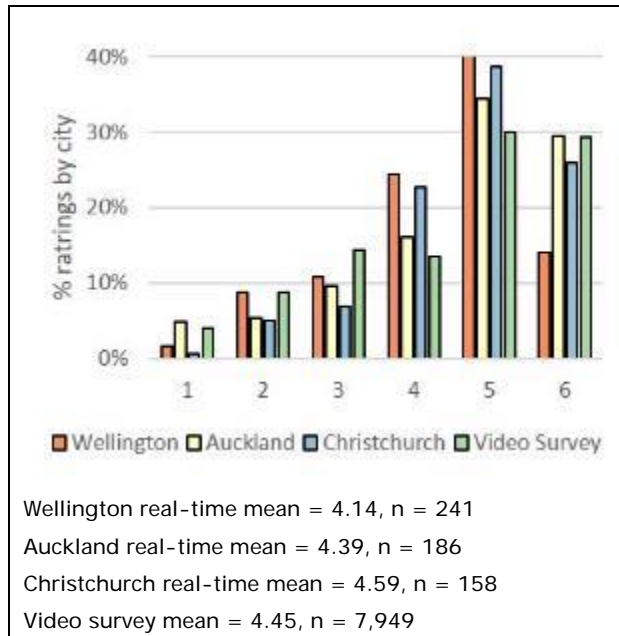
**Table 4.5** Yes/No willingness-to-ride statistics by cycling affiliation for video survey

Affiliation	No	Yes
None	11.5% (814)	88.5% (6,289)
Club/Group	6.9% (174)	93.1% (2,348)
Advocate	7.2% (99)	92.8% (1,267)
Professional	8.3% (75)	91.7% (833)

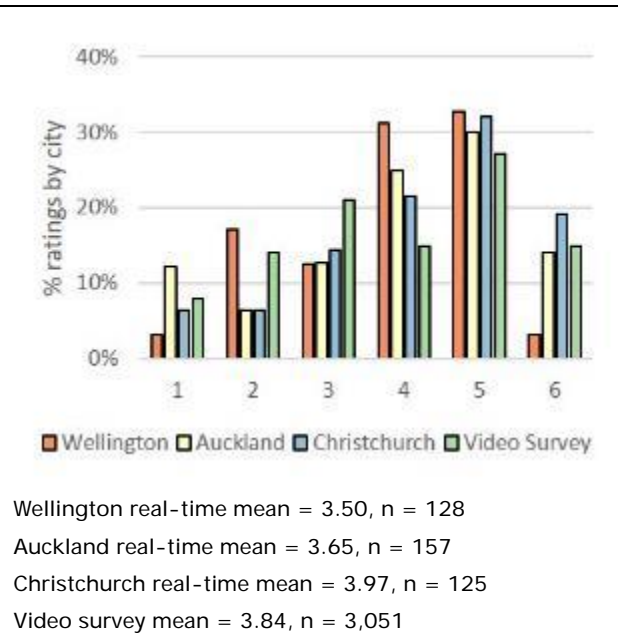
#### 4.1.2 Ratings across study locations

Overall ratings at midblocks and intersections varied slightly between cities. Wellington ratings were relatively low for both midblock and intersection segments, while Auckland and Christchurch ratings were slightly more positive. The most notable difference was the relatively low proportion of highly positive ratings in the top category for both midblocks and intersections in Wellington. The mean video survey rating and distribution of ratings for both midblocks and intersections was largely comparable to the real-time ratings for each city.

**Figure 4.9** Distribution of overall perception ratings for midblocks by real-time and video surveys



**Figure 4.10** Distribution of overall perception ratings for intersections by real-time and video surveys



Despite not being informed which specific city the infrastructure videos were sourced from, online respondents reported unwillingness to ride was broadly in line with the real-time ratings given by the respective riders in the three cities. Wellington-based videos attracted a higher percentage of unwilling viewers compared with the other cities, while Auckland was relatively good. This was largely driven by the mixed traffic videos all coming from Wellington footage so was not unexpected.

**Table 4.6** Yes/No willingness to ride statistics by location of cycle infrastructure for video survey

City	No	Yes
Wellington	14.4% (357)	85.6% (2,120)
Auckland	4.5% (115)	95.5% (2,466)
Christchurch	7.5% (205)	92.5% (2,522)

### 4.1.3 Correlation between real-time perception ratings

Tables 4.7 to 4.9 present correlation coefficients between the individual rating scores riders in the real-time study component provided for different segment types. As expected, there is generally a moderate to strong correlation between overall ratings and the sub-ratings. For on-road midblocks a stronger correlation is seen for perceptions of traffic safety, surface quality and space; off-road midblocks have less variation but a slightly stronger correlation with space and at intersections traffic safety and provision of cycle infrastructure demonstrate the strongest correlation with overall perceptions.

**Table 4.7** Correlation matrix for rider ratings on midblock on-road segments

	Overall rating	Rider experience	Traffic safety rating	Surface quality rating	Attractiveness/amenity rating	Usable space rating
Overall rating	1.00					
Rider experience	0.02	1.00				
Traffic safety rating	<b>0.74**</b>	0.04	1.00			
Surface quality rating	<b>0.65**</b>	0.06	<b>0.56**</b>	1.00		
Attractiveness/amenity rating	<b>0.43**</b>	0.06	<b>0.29**</b>	<b>0.41**</b>	1.00	
Usable space rating	<b>0.68**</b>	0.07	<b>0.64**</b>	<b>0.55**</b>	<b>0.39**</b>	1.00

NB: \*\* significant to 0.05

**Table 4.8** Correlation matrix for rider ratings on midblock off-road segments

	Overall rating	Rider experience	Attractiveness/amenity rating	Surface quality rating	Usable space rating	User conflict rating
Overall rating	1.00					
Rider experience	-0.08	1.00				
Attractiveness/amenity rating	<b>0.52**</b>	-0.26	1.00			
Surface quality rating	<b>0.59**</b>	-0.11	<b>0.44**</b>	1.00		
Usable space rating	<b>0.63**</b>	-0.09	<b>0.38**</b>	<b>0.55**</b>	1.00	
User conflict rating	<b>0.49**</b>	0.00	-0.02	<b>0.40**</b>	<b>0.50**</b>	1.00

NB: \*\* significant to 0.05

Table 4.9 Correlation matrix for rider ratings at intersections

	Overall rating	Rider experience	Traffic safety rating	Surface quality rating	Cyclist infra. provision rating	Delay rating
Overall rating	1.00					
Rider experience	0.07	1.00				
Traffic safety rating	0.78**	0.06	1.00			
Surface quality rating	0.49**	0.09	0.45**	1.00		
Cyclist infra. provision rating	0.70**	0.03	0.68**	0.45**	1.00	
Delay rating	0.29**	-0.04	0.20**	0.23**	0.19**	1.00

NB: \*\* significant to 0.05

#### 4.1.4 Summary

This section highlights several key trends:

- Males rated cycling infrastructure more positively than females. This was more pronounced in the real-time ride data than for the video survey and was possibly influenced by a lower number of female riders in this part of the study.
- Older riders in the real-time rides rated slightly more positively than younger riders. There was little difference in ratings by age for the video survey.
- Expert and advanced riders rated much more positively compared with beginner and intermediate riders in the video surveys.
- Participants who stated they had a cycle advocacy affiliation rated less positively compared with all other participant groups.

## 4.2 Cyclists' perceptions of midblock facilities

Midblock cycling facility types of most interest to this study that were rated during the real-time rides were:

- shared pathways – 16 segments
- separated cycle lanes – 13 segments
- painted cycle lanes – 12 segments
- neighbourhood greenways – 2 segments
- bus lanes – 3 segments
- mixed traffic environments – 8 segments.

These types broadly align with the increasing variety of infrastructure being designed and built in New Zealand, including neighbourhood greenways, which are becoming more common in suburban settings.

For each midblock segment, riders were asked to rate across multiple elements:

- overall perception
- traffic safety (except for on off-road paths)
- conflict with other cyclist and pedestrian users of the facility (only on off-road paths)
- attractiveness of the facility and surrounding environment
- surface quality
- space or width available.

### 4.2.1 Shared pathways

A range of shared pathways was rated during the real-time rides. These pathways can mostly be grouped into two distinct types:

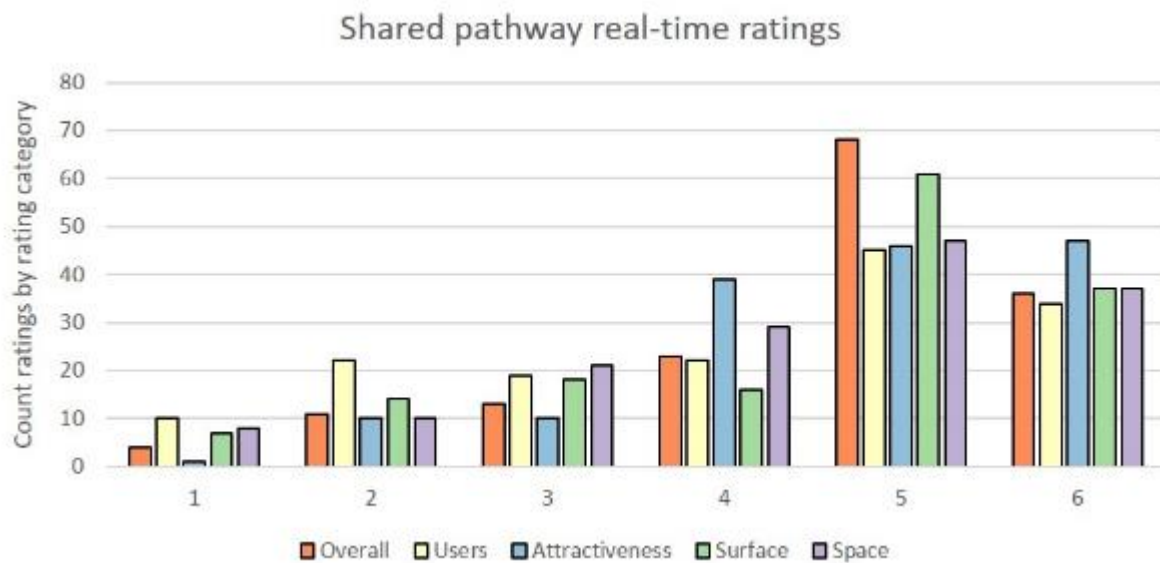
- Paths adjacent to a road that are designed to completely separate cyclists and pedestrians from vehicle traffic but follow the same route.
- Paths that have high amenity value and are provided close to attractive natural environments (eg waterfront locations). These routes may or may not follow a road and instead prioritise amenity values.

Overall, shared pathways were rated highly by riders during the real-time rides. Mean ratings by CLOS element were:

- overall perception mean = 4.6, n = 155
- conflict with other users (higher value equals lower conflict) mean = 4.1, n = 152
- attractiveness mean = 4.7, n = 153
- surface quality mean = 4.4, n = 153
- available space mean = 4.4, n = 152.

The distribution of real-time ratings is shown in figure 4.11, where there is evidence of a skew towards more positive ratings across all CLOS elements.

Figure 4.11 Distribution of ratings for shared pathways from real-time rides



Conflict with pedestrians was a commonly cited issue on shared pathways, even where riders provided a relatively high score for 'other users' there were a number of comments recounting negative past experiences. Two shared paths in particular caused issues for our riders, these were: the Northwestern Cycleway in Auckland and the Rolleston Ave shared pathway in Christchurch.

The Northwestern Cycleway has a relatively steep gradient and curves to the left as cyclists travel downhill. This two-way shared pathway creates conflict between cyclists and pedestrians when relative speeds are high and the space to overtake is limited if there is a two-way flow of users. The mean downhill ratings for this section were 3.7 for overall perceptions, 3.5 for user conflicts and 3.0 for available space, while uphill mean ratings were 3.3, 3.8 and 3.3 respectively. Both sets of means are lower compared with the overall mean values for all shared pathways combined. The width of this facility is 3.0 m. Comments from this section include:

*Lots of pedestrians and cyclists going the other way, bottleneck.*

*Too much potential for conflict, needs separation and to be wider.*

*Poor sight line in places, poor surface.*

*Blind spot.*

*Too narrow, everyone goes at a different speed.*

*Would rather ride on the road.*

Figure 4.12 Sections of the Northwestern Cycleway shared path



The rated segment of Rolleston Ave in Christchurch passes by the Canterbury Museum and entrance to the Christchurch Botanic Gardens. This is a very high foot traffic area and most of our riders encountered at least some level of conflict with pedestrians in this space. Overall our riders rated this section positively, with a mean rating of 4.2, but the facility scored low for user conflict at 2.8. It is worth noting that despite these conflicts participants still rated the available space relatively well with a mean rating of 4.1. The width of the section varies, at the entrance to the gardens and museum it is very wide before narrowing to 2.7m. Comments from riders on the Rolleston Ave shared pathway include:

*Pedestrians use the whole width, there is no sharing.*

*Definitely not a fast or efficient route at busier times – need to slow for tourists, runners and walkers. Cyclists going fast along here are a hazard and freak other users out.*

A route around Wellington waterfront shared pathway was also ridden. This route takes riders through a variety of spaces ranging from very wide (15+ metres) sections to narrow bridges. This iconic waterfront location is popular with pedestrians and other non-cycle modes so there are a lot of users in the same space, especially on a nice Saturday day as our riders enjoyed.

Figure 4.13 Sections of the Wellington waterfront shared path (left) and Frank Kitts Lagoon bridge (right)



Figure 4.14 Mean ratings for Wellington waterfront segments from real-time rides



Despite this busy space, all segments of the Wellington waterfront shared space were rated positively overall. Attractiveness ratings were high, as were perceptions of surface quality on the two open space areas (Marina and Te Papa sections). The two bridges have been built intentionally with rough surfaces and this is reflected in the ratings here. Available space was also rated relatively high, except for the Frank Kitts Lagoon bridge which is 3 m wide compared with 3.6 m on Chaffers Bridge, 8 m at the Marina section and 14 m at the Te Papa section. With a high volume of pedestrians, the Frank Kitts Lagoon bridge was also rated relatively low for user conflicts compared with the other segments.

Despite some user conflicts and tight spaces, the area was rated very highly overall. This reflects the purpose of this space as a recreational and mixed-use environment compared with other segments, such as the Northwestern Cycleway, which are much more functional in nature and are there to move cyclists and pedestrians from one place to another. Our riders were more accepting of these conflicts and less influenced by them in their overall perception due to the high amenity value of the area and the acknowledgement that cycling is not necessarily the priority here. Comments reflecting this included:

*High pedestrian area – cyclists give way rule essential.*

*Good to have pedestrian priority reminder.*

*Can get very busy with foot traffic but very safe.*

*Nice but slow.*

While our riders were required to cycle here for the study, some stated that this was not normally an area they would ride through given the level of foot traffic and because pedestrians are not always aware of cyclists approaching them at relatively high speeds.

In the video survey, the Northwestern Cycleway was included with varying levels of pedestrian and cyclist traffic. Overall the facility was rated well but in the video clip with an increased number of cyclists coming in the opposite direction the overall rating distribution was more negative, with the only difference being the number of other users.



### 4.2.2 Separated cycle lanes

Overall, cycle lanes with separation from traffic were rated most positively compared with all other facility types during the real-time rides (figure 4.15).

Riders' ratings for other aspects of these facilities (traffic, attractiveness, surface quality and available space) were also generally high and largely mirrored the overall ratings:

- overall perception mean = 5.2, n = 132
- traffic safety mean = 5.0, n = 111
- attractiveness mean = 5.0, n = 122
- surface quality mean = 5.3, n = 132
- available space mean = 4.9, n = 122.

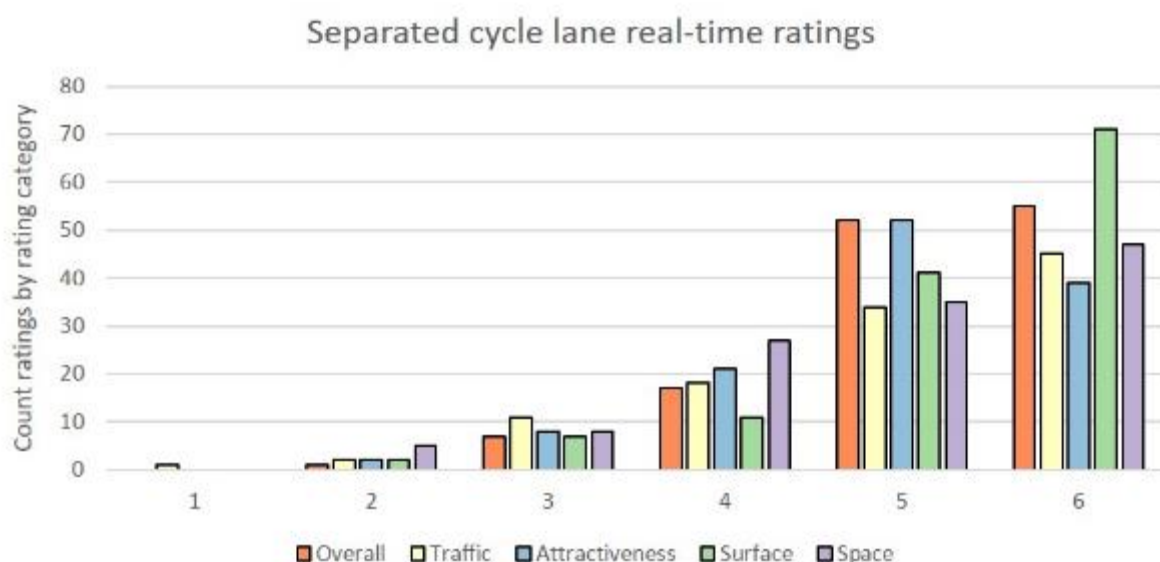
Where separated cycling facilities were rated low this was generally influenced by cyclists interacting with drivers in some way. These interactions were on separated cycle lanes that cross side streets and driveways where drivers cross the path. Comments about these events included:

*Turning cars can cut you off and there is no way to prevent this, you can't cycle defensively.*

*Cars turning in and out of side road often don't look for cyclists, poor visibility of pedestrian crossing.*

*Cars pulling out to see traffic block the cycleway.*

Figure 4.15 Distribution of ratings for separated cycle lanes from real-time ratings



The separated cycle lane heading west up Carlton Gore Road attracted a number of comments about safety from vehicles around driveways, though many riders who cited these concerns still rated the segment high due to no issues being experienced directly on the day.

Following the real-time rides the research team reviewed footage of the rides and noted that riders on the northern segment of Rutland Street in Christchurch (north of Innes Road, see figure 4.20) travelled at some of the highest speeds of all riders in the study (average speed was over 25 km/h). This section of

separated cycle lane is very high quality with a smooth surface, lots of space, and is on a section of suburban road network that has relatively low volumes compared with much of the rest of this route. While the cycle lane itself is of high quality, it passes many residential driveways with high fences obscuring driver sight lines. If a vehicle is reversing it is likely the rear of the car would need to be across some of the cycle lane before the driver had a view of the street. Just one of our riders encountered a reversing vehicle, though it was well ahead of the rider who had plenty of time to respond. At the speeds many of the riders felt comfortable cycling at on this segment, the potential for conflict with a reversing vehicle would be high if a driver emerged with little warning.

Just one rider commented on the potential for this conflict on the Rutland Street segment stating:

*A little nerve wracking that cars might come fast out of driveways, most driveways have high fences hiding cars up them.*




Riders were more likely to comment about the quality of this facility and their cycling experience which was generally very positive. One rider commented:

*Amazed. Never ridden before and was very impressed. A cyclist's own highway!*

The nature of separation between cyclists and the live traffic lane varied between routes and segments, buffer types included:

**Table 4.10 Examples of separated cycle lanes and buffers rated during this study**

Buffer type	Study example
Planter boxes (n=2) (two-way facility with no driveways on rated section)	<p>Figure 4.16 Quay Street, Auckland</p> 
Separated lane with vertical posts/bollards (n=1)	<p>Figure 4.17 Victoria Street, Wellington</p> 

Buffer type	Study example
Raised lane with no vertical buffer (n=4)	<p><b>Figure 4.18</b> Colombo Street, Christchurch</p> 
Low concrete buffer and parked cars to right of lane (n=3)	<p><b>Figure 4.19</b> Carlton Gore Road, Auckland</p> 
Low concrete buffer (n=3)	<p><b>Figure 4.20</b> Rutland Street, Christchurch</p> 

There was some variation in rider ratings by buffer type for separated cycle lanes. The percentage of riders who rated facilities a 5–6 on the six-point scale was in order:

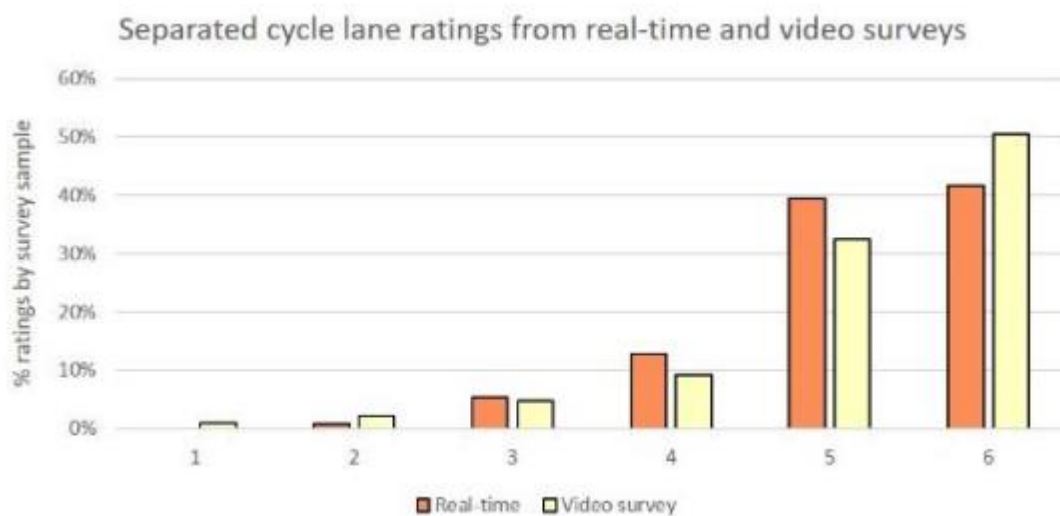
- |   |  |       |
|---|--|-------|
| 1 | Low concrete buffer and parked cars to right of lane | 90.0% |
| 2 | Planter boxes  | 89.5% |

3	Raised lane with no vertical buffer	80.0%
4	Low concrete buffer	78.8%
5	Separated lane with vertical posts/bollards	50.0%

It is unlikely that this variation was due solely to the buffer type itself, as these facilities varied across other factors too. For example, a more prominent physical buffer (eg planter boxes) not only provides separation from the adjacent motor vehicle lane, but is likely to be provided on segments where there are no driveways or side roads that require vehicles to cross the cycle lane. So decisions about buffer type are a function of the road layout and adjacent land use, and these external factors are known to influence riders' perceptions. The particularly low score for separated lane with vertical posts had a sample of only 1. It has a range of features that may explain the score; however, the height of the post in this instance can limit the effective width of the path (ie due to width of handlebars). The low number of facilities by buffer type does not allow for an indepth analysis of these effects independently of other CLOS factors.

Separated cycle lanes were rated similarly by both the real-time and video survey participants, though overall the video survey was more skewed towards positive perceptions of separated facilities than was seen from the real-time distribution (figure 4.21).

**Figure 4.21** Distribution of overall perception and comfort ratings for separated cycle lanes from the real-time and video surveys



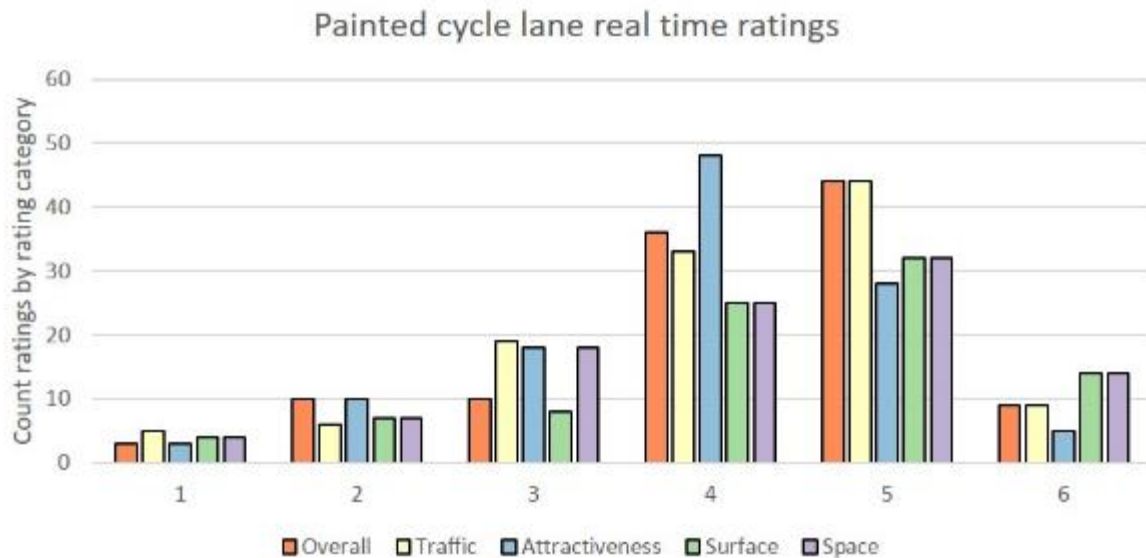
#### 4.2.3 Painted cycle lanes and sealed shoulders

Cycle lanes adjacent to vehicle traffic lanes with paint delineation were generally rated positively by real-time riders. The distribution of ratings shown in figure 4.22 is less skewed compared with the distribution for separated cycle lanes, with a cluster of respondent ratings around 4 and 5 of the six-point scale.

Painted cycle lanes were primarily rated in two distinct land use and road network environments:

- 1 Collector roads and suburban streets.<sup>4</sup>
- 2 Central city and suburban business areas.

Figure 4.22 Distribution of ratings for painted cycle lanes from real-time rides



Rider's real-time ratings for facilities in these two environments varied, with evidence that painted cycle lanes on collector roads and suburban streets have a higher overall perception compared with those in business areas (figures 4.23 and 4.24). This is related to increased traffic volumes and movements in busy business areas. On collector and residential streets 94% of overall ratings were 'positive' ratings between 4 and 6, this dropped to less than 70% in business areas. Mean ratings for overall, traffic and space between these two environments were:

Table 4.11 Mean ratings for painted cycle lanes

	Overall perception	Traffic safety	Available space
Collector roads and residential streets	4.5	4.7	4.5
Central city and suburban business areas	4.0	3.7	3.8

In central city and suburban business areas cyclists cited a range of negative and potentially dangerous interactions with motor vehicles and drivers that led to relatively low ratings for traffic safety. Comments captured here included:

*Van parked across cycle lane, lots of opportunities to be car doored.*

<sup>4</sup> During the real-time rides on Dominion Road in Auckland participants rated a series of painted cycle lanes. This busy stretch of road has many side roads entering it as well as on and off-ramps that the painted lanes cross. Due to this, it is difficult to separate out a midblock cycle lane effect from an intersection effect, and there is no comparable facility elsewhere in the study to tease out this effect. As such, Dominion Road painted cycle lanes have been excluded from the statistics here.

*Feel like the cycleway is intruding on car space.*

*Dangerous, should be on the inside and parked cars on the outside, danger of being hit by a car door or a car pulling out.*

*Have to have faith in others and be attentive.*

Even when riders rated these sections relatively high based on the experience they had on the day of their ride, they often included comments about the danger of car doors opening, vehicles being stopped in the cycle lane, and cars entering and leaving parking spaces.

The painted cycle lanes on Carlton Gore Road in Auckland and Papanui Road at the Merivale Shopping Centre (note that this lane ‘disappears’ temporarily through a pinch point) attracted many of these negative ratings and comments. On these stretches of road, cyclists travel between parked vehicles and moving traffic, and both were very busy when our riders were present. This made for an environment with a lot of vehicle movements where the cyclists had to proceed with great caution. More than one cyclist spoken to following their ride stated they rode as far away from the car door zone as possible, and they would normally ride out in the vehicle lane to increase their visibility and stay away from parked cars in an area like this.

Each of the painted cycle lanes on collector and suburban streets also had space for parked cars to the left of the lane. However, vehicles were often parked more sporadically along these stretches with space between and not bumper to bumper. Traffic flows in the lane were also lower in general, so overall riders spent less time between a parked and moving vehicle. There were also fewer conflicting vehicle movements ahead to watch out for such as cars coming in and out of parking spaces or taxis and delivery vehicles stopping in the cycle lane, as we saw on more than one occasion in busier business areas.

Figure 4.23 Real-time rating distribution for painted cycle lanes on collector and suburban streets

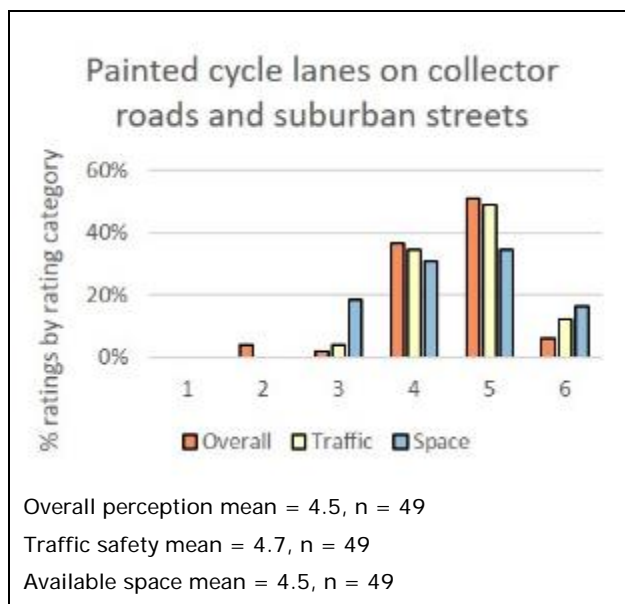
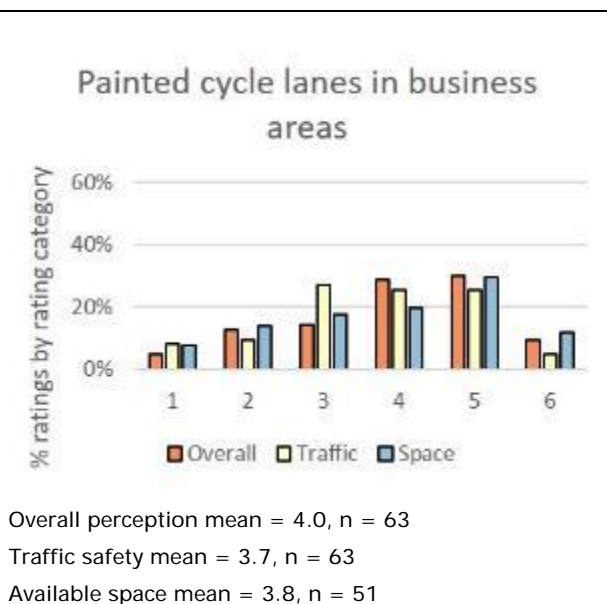


Figure 4.24 Real-time rating distribution for painted cycle lanes in central city and suburban business areas



Manchester Street in central Christchurch is a stretch of road with contrasting features within a short distance. The section of road heading north from Dundas to St Asaph Street is an old painted cycle lane with parked cars to the left of the lane (figure 4.25), while the section from St Asaph Street to Tuam Street



is a new painted cycle lane with clear markings, including a stretch of green coloured surface, and parking spaces removed for most of the block (figure 4.26).

**Figure 4.25** Manchester Street painted cycle lane: Dundas Street to St Asaph Street (heading north)

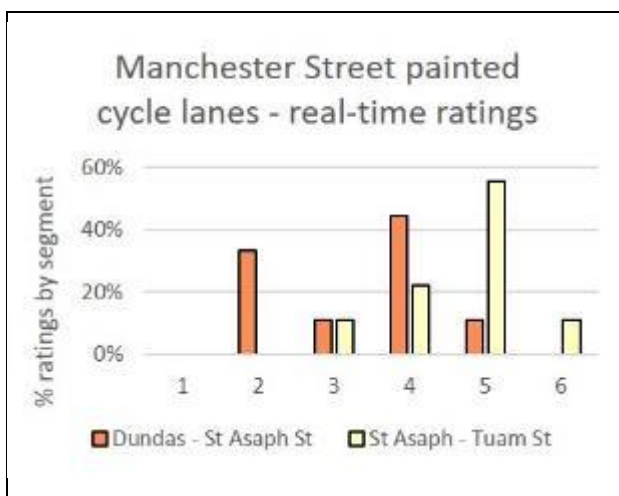


**Figure 4.26** Manchester Street painted cycle lane: St Asaph Street to Tuam Street (heading north)

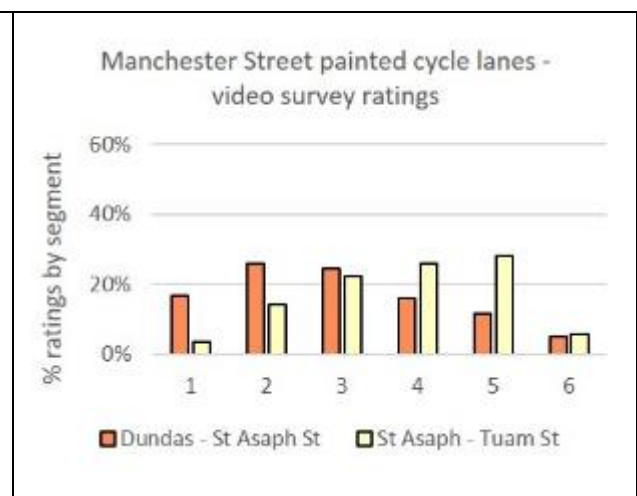


While it is a small sample size ( $n=9$ ) our riders showed a preference for the newly installed section compared with the old. Riders described the old section as having several incursions into the lane, which was very narrow where cars were parked, and cyclists were almost forced out into the motor vehicle lane to avoid the opening of car doors. In contrast, the new section was perceived to be better because it was mostly free of incursions and clutter, and the double painted lines were bold and more visible. Responses to the video survey for these two segments mirrored that of the real-time ride data, and the willingness-to-ride statistics found 25.8% of respondents were unwilling to ride on the Dundas – St Asaph Street segment, compared with 11.1% on the St Asaph to Tuam Street segment. Absence (or presence) of parking appears to be the biggest difference here, as well as perceptions of available space and the style of marking.

**Figure 4.27** Manchester Street painted cycle lane sections – real-time perception ratings



**Figure 4.28** Manchester Street painted cycle lane sections – video survey ratings

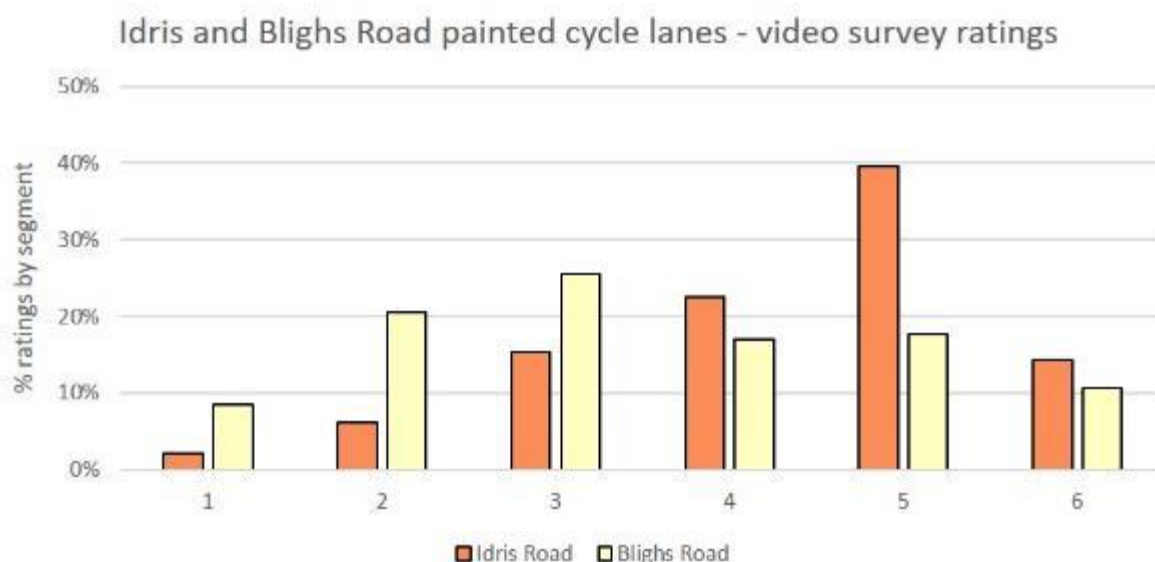


Blighs Road and Idris Road in Christchurch were both included in the real-time and video surveys. These two roads connect to each other (Idris turns into Blighs if travelling north) and each have a painted cycle lane for cyclists between residential parking spaces and the motor vehicle lane.

During the real-time rides both of these segments were rated positively (Idris mean rating = 4.8, Blighs mean rating = 4.6) with no ratings less than 4 assigned to either site. However, responses to the video survey were less positive and showed a contrast between the two facilities (figure 4.29). Two videos of Idris road were included in the survey, one showing overtaking vehicles and the other not, while the video of Blighs Road had overtaking vehicles present too. The major difference between Blighs Road and Idris Road videos is the number of parked cars, more on Blighs Road than on Idris in both videos. There is also a pinch point midway along Blighs Road where the shoulder beside the cycle lane disappears. This pushes the cyclist slightly toward overtaking vehicles and combined with parked cars at this point created the perception of reduced space.

Sealed shoulders with no vehicle parking, which for most purposes operate the same as painted cycle lanes, were not mentioned in the study. As such, we recommend including in the same rating scale.

**Figure 4.29** Distribution of comfort ratings for Blighs Road and Idris Road painted cycle lanes from the video survey



#### 4.2.4 Shared roadway

Shared roadways include several types of general traffic lanes or zones that can be designed to accommodate cycling. In New Zealand these include:


- neighbourhood greenways, also known as 'quiet streets', are streets with low motor vehicle volume and generally include physical measures to restrict vehicle drivers' movements
- bus lanes and transit lanes
- shared zones
- mixed traffic.

For this study we have grouped mixed traffic roadway types by the surrounding land use:



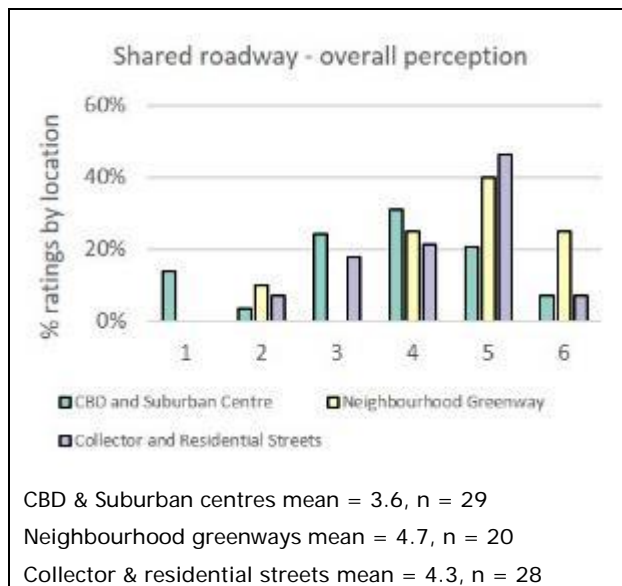
- Central city and suburban business areas – these tend to be busy environments with a number of cyclist and vehicle driver interactions. On-street parking and busy commercial driveways add to this.
- Collector roads and low-volume residential streets – these vary in nature a lot but often include on-street parking and residential driveways, and where cyclists may spend a lot of time riding in the same lane as motor vehicle traffic.

**Table 4.12** Examples of shared roadway segments rated during this study

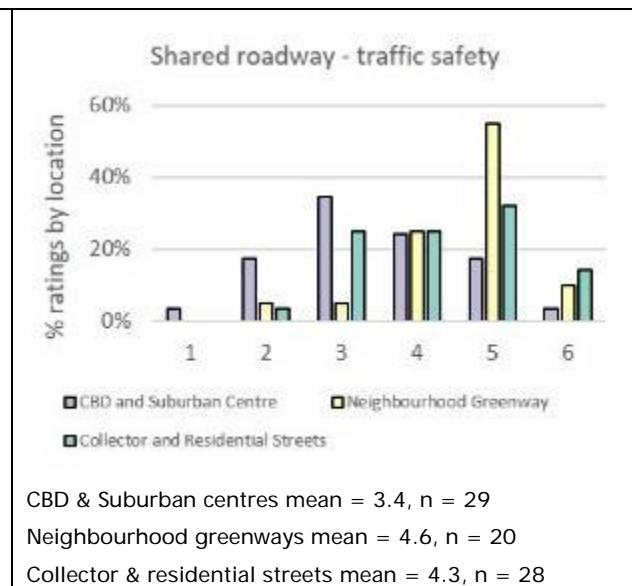
Land use or road network environment	Example segment
Mixed traffic in central city and suburban business areas (n=4)	<p data-bbox="810 589 1219 618"><b>Figure 4.30</b> Tory Street, Wellington</p> 
Mixed traffic on collector roads and low-volume residential streets (n=4)	<p data-bbox="810 1081 1198 1111"><b>Figure 4.31</b> Ira Street, Wellington</p> 
Neighbourhood greenways (n=2)	<p data-bbox="810 1563 1241 1592"><b>Figure 4.32</b> Queen Street, Wellington</p> 

Mixed traffic conditions on neighbourhood greenways, collector roads and low-volume residential streets were generally rated quite positively for all measures, while central city and suburban business centres were rated relatively negatively for overall traffic safety and available space perceptions. As for painted and separated cycle lanes, the influence of motor vehicle traffic on riders' ratings was important, with street environments that placed riders and drivers in the same space with the potential for conflict leading to less favourable perceptions.

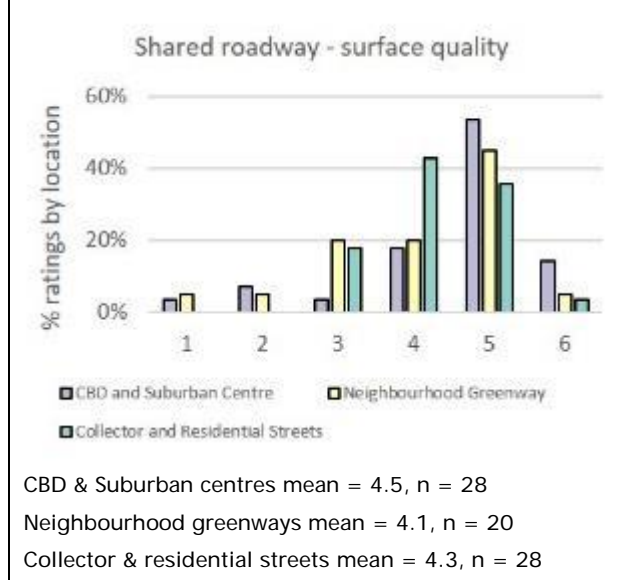
**Figure 4.33 Shared roadway – overall perception ratings from real-time survey**



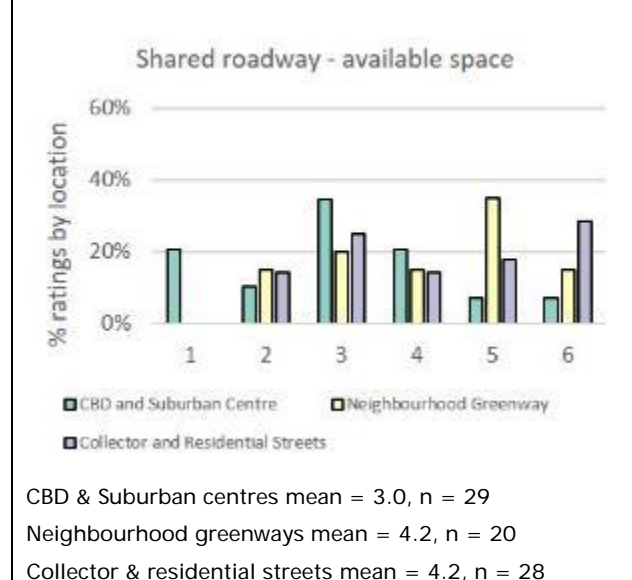
**Figure 4.34 Shared roadway – traffic safety ratings from real-time survey**



**Figure 4.35 Shared roadway – surface quality ratings from real-time survey**



**Figure 4.36 Shared roadway – available space ratings from real-time survey**



The distribution of 'available space' is worth noting, particularly for collector and residential streets and neighbourhood greenways. On these road types, a few riders provided low ratings for available space, even where there was physically a lot of room available. Most of the low ratings for available space in CBD and suburban centres were on High Street in Auckland, a narrow one-way street with parked vehicles on

both sides of the rider and little space for a vehicle driver to overtake a slower moving cyclist. Comments from riders on High Street included:

*The whole street is a door zone practically.*

*You have to ride almost in the centre to be out of the door zone.*

The route selection did not produce the necessary variation to quantitatively demonstrate the influence of road network design, traffic conditions and surrounding land use on cyclists' perceptions of CLOS for this study. In chapter 1 we propose a range of CLOS factors that are most likely to influence cyclists' perceptions on shared roadways, but we cannot produce a rating scale for values of each of these based on the data collected for this study.

Further, while we group shared roadways together here, it is likely that perceptions of CLOS will vary by type of road environment, and so the rating system will be unique for each (for example the influence of traffic volume and speed on neighbourhood greenway will differ from a multi-lane mixed traffic environment).

#### 4.2.5 Willingness to ride for different facility types

Here we present the relative proportions of cyclists who in their online video survey responses answered *yes* to the question 'Would you ride here?' for each of the videos watched. Overall, our participants appeared to be quite 'willing' to cycle on most facility types, with even shared roadway/mixed traffic environments being rated by 86% of respondents as places they would cycle (figure 4.37).

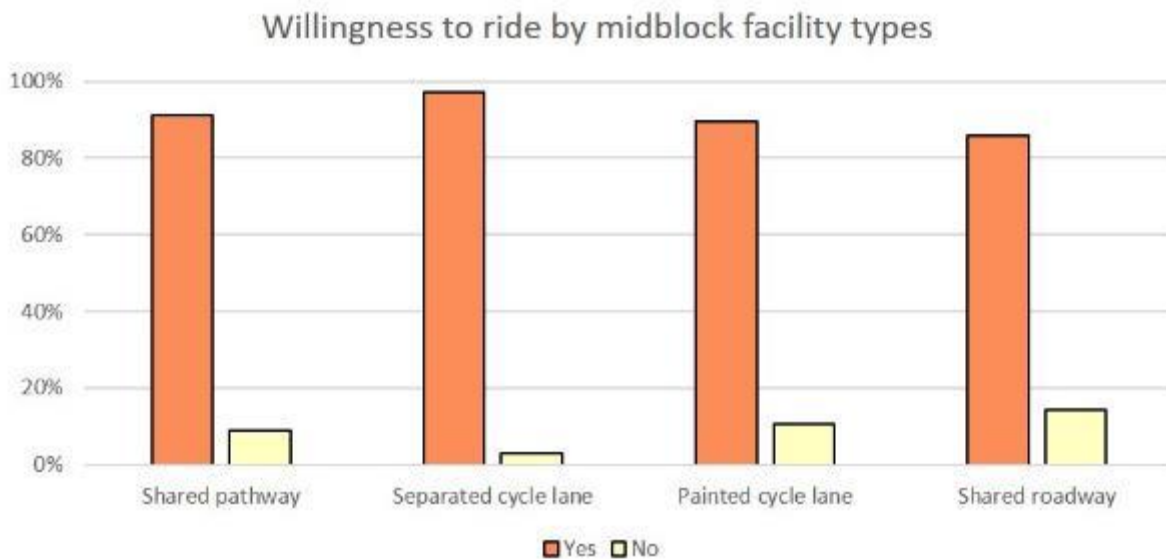
There was, however, a discernible increase in willingness to ride where there was increased separation on cycle facilities, with shared pathways (91%) and separated cycle facilities (97%) most favoured.

When we look at how cyclists with varying levels of experience rated these facilities there is clear evidence that separation from vehicle traffic has an influence on willingness to ride for beginner and intermediate cyclists (figure 4.38).

For shared pathways and separated cycle lanes most cyclists (regardless of experience level) stated they would be willing to cycle in the environment shown for each video. For non-separated facilities, however, such as painted cycle lanes and shared roadway/mixed traffic environments, there was a clear trend of experience influencing perceived willingness to ride.

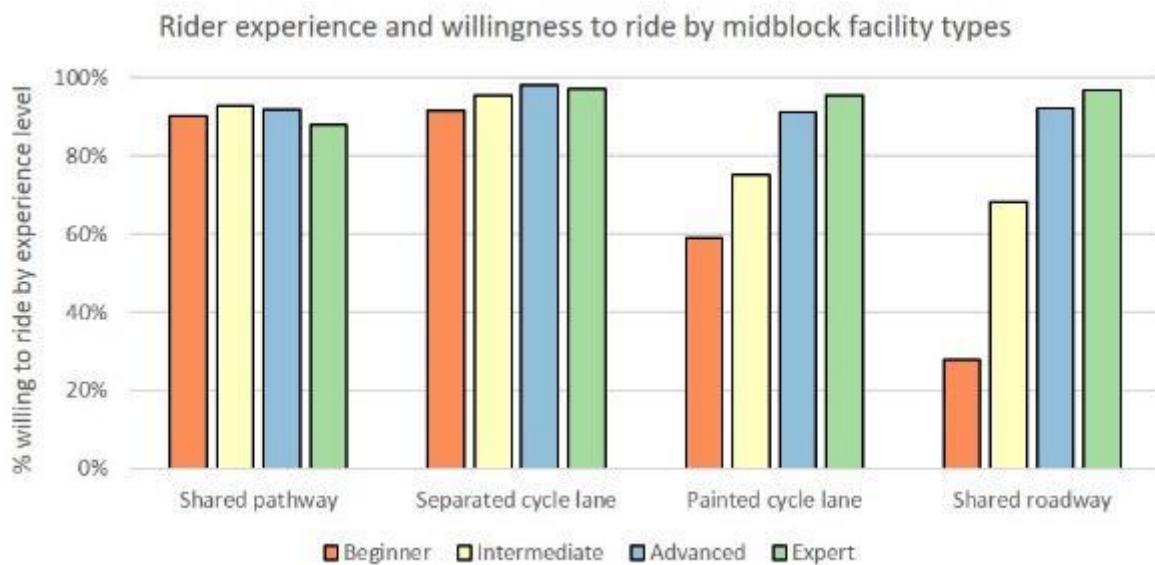
Advanced and expert cyclist groups rated non-separated facilities in much the same way as shared paths and separate cycle lanes, with roughly 90% or more of all riders in these groups stating they would be willing to ride in the environment depicted in the video no matter the facility type. There was a slight reduction for advanced and expert riders on shared paths, which indicated that about 1 in every 10 experienced riders might be motivated to take alternative routes if they were available.

Figure 4.37 Cyclists' willingness to ride by midblock facility type



In contrast, intermediate and beginner riders' willingness to ride on painted cycle lanes increasingly reduced. Just 75% of intermediate and 59% of beginner riders stated they would be willing to ride on the painted cycle lanes as shown, and 68% and 28% on shared roadway environments respectively.

Figure 4.38 Cyclist experience and willingness-to-ride statistics for midblock facilities



Cross-tabulation was used to examine the relationship between cyclist experience and willingness to ride on different facility types using the data presented in figure 4.38. The chi-square statistic tells us how much difference there is between the observed counts and the counts that would be expected if there was no relationship between experience and willingness to ride.

Key findings by rider experience were:

- For beginner cyclists, more respondents stated they would be willing to ride on shared pathway and separated cycle lanes, but less willing to ride on shared roadway environments. Painted cycle lanes, while showing a low willingness to ride in figure 4.38, did not show a significant change in expected compared with observed values. Beginner riders appeared to have a preference for separation from motor vehicle traffic. Again, we note the very small beginner sample size which has limited the ability to draw a reliable conclusion from these statistics.
- Intermediate cyclists showed a significantly higher willingness to ride on shared pathway and separated cycle lanes, and a significantly lower willingness to ride on painted cycle lanes or shared roadway environments. As indicated by beginners, intermediate riders also had a strong preference for separation from motor vehicle traffic.
- Advanced cyclists showed a significantly lower willingness to cycle on shared pathways, painted cycle lanes and shared roadway environments, and a significantly higher willingness to ride on separated cycle lanes. Advanced cyclists therefore preferred separated facilities relative to other types, though their overall willingness to ride on any facility type was still high.
- Expert riders showed a significantly lower willingness to ride on shared pathways, and no significant variation between observed and expected willingness to ride on other facility types. We suggest that apart from some riders who have a preference to avoid shared pathways, expert riders are generally willing to ride on most facilities or road environments.

#### 4.2.6 CLOS factors influencing cyclists' perceptions

This section describes the key factors, and interaction between factors, identified by this study as being important influencers of cyclists' perceptions of CLOS.

##### 4.2.6.1 Motor vehicle traffic

As expected, motor vehicles were the most commonly discussed aspect of our real-time riders' experience, and as supported by previous work, is likely to be the most influential factor in cyclists' perceptions of CLOS, especially for on-road and painted cycle lane environments.

The desired range of motor vehicle volumes and speeds of overtaking vehicles was not achieved for this study,<sup>5</sup> so there is insufficient variation in both to quantitatively determine how varying levels of separation from traffic influence cyclists' perceptions of motor vehicle traffic safety. Though, despite this we have collected a rich commentary of motor vehicle-related perceptions from the real-time rides (some of these comments have been presented in previous sections of this chapter), and can make use of data about parked vehicles, conflicts at driveways/side roads, and presence of motor vehicles to better understand how these interactions and conflicts influence cyclists' perceptions of different road types.

Three motor vehicle factors appear to have a relatively high influence on our riders' perceptions:

- volume of overtaking vehicles in the adjacent lane
- vehicle movements across the path of cyclists, including vehicles entering and exiting driveways and parking spaces, and vehicles that stopped directly in front of riders in the cycle lane itself
- the overtaking buffer/gap between riders and overtaking vehicles.

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<sup>5</sup> This is a function of the study design which limited the number of riders in each route per day. A rider may spend less than one minute on a specific segment of interest, so across the full day many segments have video footage of fewer than 10 minutes total duration captured. This limitation is further discussed in chapter 7.

The nature of how real-time ride participants have rated facilities and streets based on motor vehicle traffic also presents challenges for analysis. We can see in the comments that some individuals have rated a facility poorly based on prior experiences, and not the actual experience on the day. In contrast we had a small number of riders who provided very good scores even though they noted a negative experience (eg a taxi double parked in a cycle lane that they rode around) as they saw this as a non-normal experience, outside of which their overall perception was good.

Vehicle speeds have been previously shown to influence riders' perceptions; however, just two roads in the study had speed limits greater than 60 km/h. Consequently, the small number of observations did not allow for a comparison of perceptions of facility types by relatively high and low vehicle operating speeds.

In 2017, WSP Opus Research conducted a study on behalf of the Transport Agency to examine current overtaking interactions between motor vehicles and cycles in the Wellington region (Balanovic et al 2016). This study captured data about overtaking speeds and overtaking gaps on a range of road network hierarchies and speed limits. The data was collected using an instrumented bike ridden by volunteer riders, some of whom rode pre-selected routes while others were given the bike for up to a few days and asked to ride wherever and whenever they liked. While the bike recorded overtaking interactions (>6,500 in total), riders were asked to flag 'uncomfortable' events by pushing a button on the handlebars. Analysis of this data enabled the research team to associate uncomfortable events with overtaking interactions and examine what it was about an interaction that was driving discomfort.

We have applied the findings of the previous study to the current research. Key findings are:

- 1 On roads with a  $\leq 60$  km/h speed limit the acceptance of a vehicle overtaking buffer/gap is just 50% for distances of less than 0.5 m (though there were low recorded observations in the study at this range). Acceptance increases to 79% for gaps of 0.5–0.99 m, and is more than 90% for gaps of 1 m and above.
- 2 On roads with a  $> 60$  km/h speed limit the acceptance of overtaking gaps smaller than 1 m was just 57% (again a small number of recorded observations), increasing to 85% for 1.00–1.49 m and more than 95% for 1.50 m and above.
- 3 The presence of a sealed shoulder or painted cycle lane reduced the number of flagged uncomfortable interactions from 47% to 25% compared with roads with no shoulder space (mixed traffic environments).

The findings of the previous study have been applied to the CLOS factor scoring for buffer/gap in the tables presented in chapter 5.

#### 4.2.6.2 Facility width

Facility width and perceptions of available space appear to be strong influencers of cyclists' perceptions of CLOS. We measured width at the distance available on the pavement, but other studies have also examined this from the perspective of 'effective width' which considers physical objects such as parked vehicles, post and fences, and the gap between cyclists and drivers in vehicles on adjacent lanes. These physical objects are likely to play a role in riders' perceptions of effective width, and it is likely that different objects influence these perceptions differently even if the actual space is the same. For example, a rider travelling on a path bounded by a fence or hedge on both sides might be likely to have a more positive perception of space compared with a rider who experiences the same effective width but with a parked vehicle on one side and moving traffic on the other.

We do not have sufficient data to establish an 'ideal' effective width for all facility types and road environments, but we can establish that perceptions of available space are highly influenced by the

presence of other users. On shared paths, conflict with other users influenced our riders' perceptions of available space, where there was low conflict and the ability to travel freely available space was perceived positively. Where several other users were present creating conflict, it was more likely for available space to be rated less well, along with a poor rating for conflict with other users. User behaviour becomes important on these segments to make best use of limited space, eg pedestrians keeping left and not walking in groups across the path, and cyclists travelling at an appropriate speed that allows them to give way to other users.

On painted cycle lanes and in mixed traffic environments a better measure of available space is likely to be the gap a motor vehicle driver can provide to a cyclist as they overtake. Most of the painted cycle lanes in this study were positioned between parked vehicles and adjacent motor vehicle lanes. The presence of parked cars reduced the effective width of the cycle lane by pushing our riders out of the door zone toward the adjacent vehicle lane. Riders were still cycling within the painted lane and vehicles overtaking outside of it but the overtaking gap between the two was reduced. On some of these segments some riders stated they would rather ride in the adjacent traffic lane to be more visible to drivers.

#### **4.2.6.3 Surface quality**

The instrumented bike captured data relating to surface roughness via an accelerometer, and our real-time riders rated the surface quality for all segments during their ride. Analysis of measured roughness against perceived quality yielded a low association; however, it is clear that poor quality surfaces were an important driver of CLOS for cyclists.

Surface quality, overall, was generally rated highly, with our riders often stating in their post-ride debrief that it was not something they thought about while riding until they encountered a very low-quality surface. The Northwestern Cycleway shared path in Auckland was a good example of this with many riders commenting on the poor quality of the surface on some sections.

The instrumented bike is sensitive enough to detect the difference in surface quality between chipseal and asphalt surfacing; however, the rider ratings did not reflect a major difference in perceptions between surface types. This further suggests that substantial deterioration is likely to be more influential. However, this perception could be different depending on the bike being ridden – the instrumented bike is a 'commuter' style bike with front suspension. A cyclist on a road bike would probably experience the roughness of a chipseal surface differently from our study group.

#### **4.2.6.4 Gradient**

Some uphill and downhill segments were included in this study, though we did not attempt to rate these through the video survey as it is difficult to interpret gradients from chest mounted video footage. On two of the steeper uphill segments, Pirie Street in Wellington and the Northwestern Cycleway in Auckland, our riders commented on the steepness, but it was difficult to isolate the effect of this on riders' perceptions from other factors in the data.

The influence of gradient is likely to interact with other factors. For example, Pirie Street in Wellington is a short, but steep, uphill segment of mixed traffic. There are parked vehicles on both sides of the street and two-way traffic coming up and down. With a cyclist travelling slowly uphill a pinch point is created if two cars are approaching from opposite directions, and the parked cars reduce the overall perception of space a cyclist has as they move out from parked cars to avoid doors.

On the same Wellington route our riders then travelled down a relatively steep section of Elizabeth Street (after making their way up Pirie). Some riders commented on the steepness of the downhill section, but no references to vehicle traffic were made (this section is also one-way downhill). It is likely that at higher speeds the cyclists felt more able to move with the traffic flow, so the quality of the surface and sight lines

became quite important when travelling at high speed downhill. While on steep uphill segments the speed differential between riders and drivers is much higher and creates conflict between users.

A similar influence was demonstrated on the steep downhill section of the Northwestern Cycleway. Cyclists can easily travel at high speed down this slope, but with poor sight lines as the path curves to the left alongside trees, and with pedestrians walking in both directions, the potential for conflict between users travelling at very different speeds is high. This speed differential was often cited in comments about 'slow' pedestrians and uphill cyclists as creating conflict and prompted some riders to call for separation of modes here.

Carlton Gore Road also has uphill and downhill segments, but the gradient was not mentioned in any comments from our riders. The downhill segment is a separated cycle lane that was rated quite highly, while the uphill segment travels past many driveways and shops. As mentioned, this uphill segment was rated low because of these other factors, and it is difficult to identify how the gradient may or may not have exacerbated this. One potential benefit of the uphill segment of Carlton Gore Road is that because it is a separated cycle lane there was no mixing of modes in the same space so less potential for conflict due to speed differences here.

We have little quantitative data to demonstrate the effect of gradient on cyclists' perceptions of CLOS. Though it is likely that uphill and downhill gradients influence riders in separate ways, with uphill riders more concerned about conflicts created with vehicle traffic due to slow travel speed. While downhill riders are concerned about conflict with slower users such as pedestrians on off-road paths, and the quality of the surface and ability to be seen when travelling amongst vehicle traffic at high speeds downhill.

#### **4.2.6.5 Other cyclists and pedestrians**

The presence of pedestrians and cyclists on shared paths influenced cyclists' perceptions in both the real-time and video surveys for this study. This was certainly to be expected from the video survey where we introduced varying levels of pedestrian and cycle traffic to explore the effect of this and, as anticipated, ratings were lower than for videos with fewer conflicts.

Riders' responses during the real-time rides were valuable for teasing out this effect, and we suggest that the role of the facility or trip purpose should be considered. On shared paths where many trips are commuter type trips, that is getting from A to B in the fastest or most efficient manner, then conflicts with other users, particularly pedestrians, were viewed quite negatively. In these environments, cyclists are motivated to travel at speed, and conflicts created by a lack of space for overtaking or passing, or by speed differences between users were a poor outcome. Some of our riders stated they would go as far as riding a high-speed (70 km/h) multi-lane road adjacent to one shared path to avoid the conflicts they experienced on shared paths during their ride. Separation of modes on this type of facility was cited as a preferable treatment to improve CLOS.

In contrast, based on the feedback on our real-time rides, conflict with other cyclists and pedestrians on shared paths that serve other purposes, such as waterfront or park environments that attract many different users to move and linger in a space, was more acceptable. In these instances, the facility itself was not perceived as poor but cyclists stated they would modify their behaviour and take a different route if they were commuting. If they were cycling to enjoy the high-quality natural environment or amenity, then they would be prepared to encounter many different users and as a cyclist would expect to give way to other users.




## 4.3 Cyclists' perceptions of intersections

This study rated a range of intersection and crossings across all three cities:

**Table 4.12** Examples of intersections rated during this study

Buffer type	Study example
Signalised intersection with cycle priority phase (n=7)	<p><b>Figure 4.39</b> Rutland Street at Innes Road, Christchurch</p> 
Signalised intersection (n=11)	<p><b>Figure 4.40</b> Victoria Street at Dixon Street, Wellington</p> 
Roundabout (n=5)	<p><b>Figure 4.41</b> Coutts Road at Tirangi Road, Wellington</p> 

Buffer type	Study example
Signalised pedestrian and cyclist crossing (separated from roadway) (n=4)	<p><b>Figure 4.42 Upper Queen Street at Ian McKinnon Drive, Auckland</b></p> 

Route selection for this study was primarily focused on midblock segments to form loops. This approach led to the required variation in intersection types and CLOS design features not being achieved for the study.

As shown above, the actual number of intersections by type was low, and within these groupings there were even smaller subsets of design features (for example advance stop boxes, hook turn boxes and Barnes Dance), and movements that our riders made through each intersection (left turn, straight ahead, right turn). Because of the location of our loop rides, we were unable to test the effect of different traffic volumes and speeds while controlling for key intersection design features, for example all the roundabouts rated were single lane on 50 km/h low volume and collector roads.

Overall, signalised intersections that included a dedicated phase for cyclists were rated most positively by riders in the real-time rides for this study (table 4.13). There was some evidence of variation by experience level, with intermediate riders rating signalised pedestrian and cyclist crossings highly, while expert riders rated them low. Feedback from riders suggested that those with higher experience levels would prefer to join vehicle traffic for a quicker crossing than face a relatively long delay by using the crossing. In contrast, less experienced riders were happy to trade off time for a safe crossing separated from vehicle traffic.

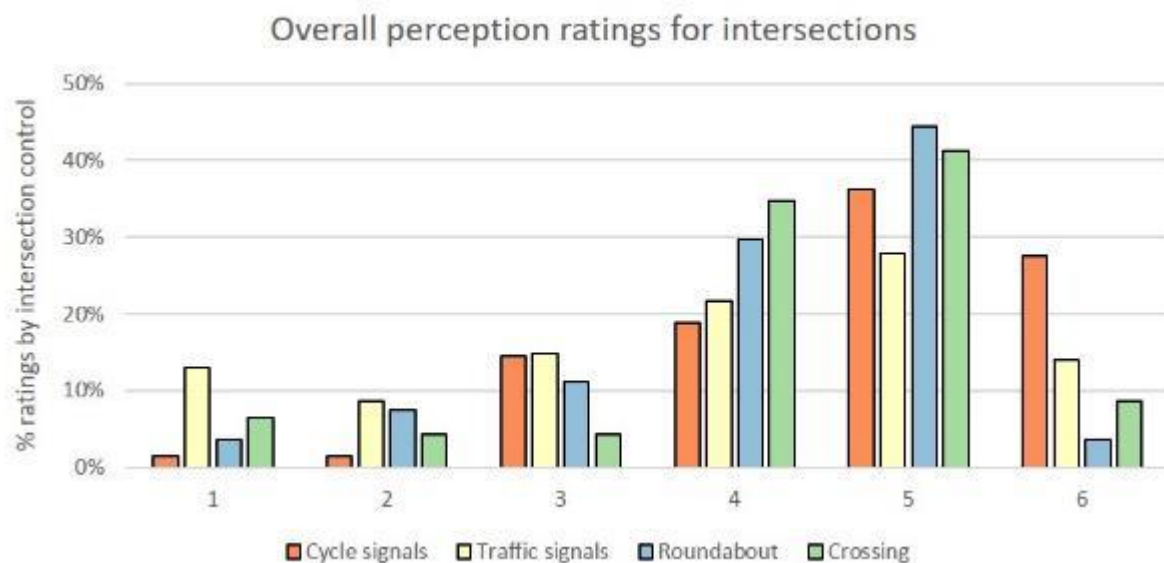
Signalised intersections that cater to all modes in the same phase and roundabouts were also perceived better by more experienced cyclists.

The rating distribution for intersections during the real-time rides is negatively skewed for all four intersection types (figure 4.43). Signalised intersections with cyclist signals were the most positively rated with approximately two thirds of riders rating these intersections a 5 or a 6

**Table 4.13 Mean overall ratings for intersection type by rider experience from real-time rides**

Intersection/crossing type	Intermediate	Advanced	Expert	Combined
Signalised intersection with cycle phase	4.3	4.6	5.0	4.7
Signalised intersection	3.8	3.5	4.3	3.8
Roundabout	3.7	4.3	4.3	4.2
Signalised pedestrian and cyclist crossing	4.8	4.4	3.5	4.3

Figure 4.43 Overall perception rating distribution for intersections from real-time rides

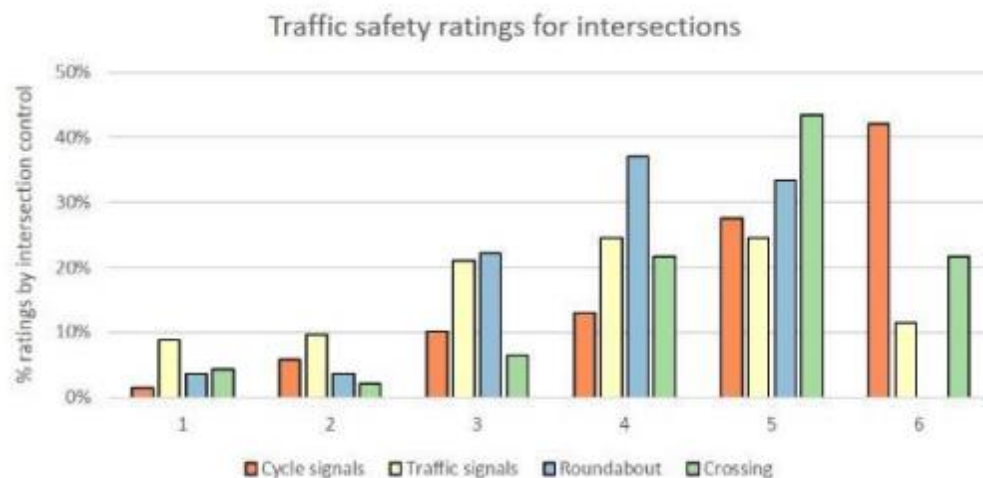


Perceptions of traffic safety show a similar pattern to overall perceptions, with signalised cycle phase intersections and crossings rated most positively (table 4.14 and figure 4.44).

Table 4.14 Mean traffic safety ratings for intersection type by rider experience from real-time rides

Intersection/crossing type	Intermediate	Advanced	Expert	Combined
Signalised intersection with cycle phase	4.6	4.8	5.1	4.9
Signalised intersection	3.8	3.5	4.2	3.8
Roundabout	3.7	4.0	4.0	3.9
Signalised pedestrian and cyclist crossing	4.9	4.4	4.5	4.6

Figure 4.44 Traffic safety rating distribution for intersections from real-time rides



At each intersection on the real-time rides our riders rated their perception of the delay that they experienced. We asked them to rate this relative to other modes, that is how much they were delayed

compared with motor vehicle traffic or pedestrians for example. The purpose of this was to understand what effect intersection design and control had on cyclist specific delays, not lengthy delays that impacted on all modes equally.

As shown in table 4.15 and figure 4.45 riders experienced the least delay at roundabouts while the worst perceived delay was at signalised pedestrian and cyclist crossings. This is unsurprising as roundabouts are give-way controlled allowing riders to make their own decision when to advance. The roundabouts included in this study were all on relatively low-volume routes so wait times were generally short. Because we asked our riders to consider delay relative to other modes it is not surprising that crossings rated relatively poorly, especially for advanced and expert riders, as it was common for a rider to have to wait through a vehicle phase before being able to cross. At intersections such as Ian McKinnon Drive in Auckland where our riders were making a right-hand turn they had to wait through two full phases to cross to one corner, wait, and then cross to the next corner, meanwhile right-turning vehicles made the turn in one phase.

Interestingly, our intermediate riders still rated crossings quite highly, better than other signalised intersections, suggesting that they are perhaps more willing to trade-off time for safety benefits and that this influenced their perceptions of delays.

**Table 4.15 Mean ratings for delays experienced at intersections by rider experience from real-time rides**

Intersection/crossing type	Intermediate	Advanced	Expert	Combined
Signalised intersection with cycle phase	4.2	4.6	4.6	4.5
Signalised intersection	4.2	4.2	4.3	4.2
Roundabout	5.7	5.0	5.0	5.2
Signalised pedestrian and cyclist crossing	4.5	3.0	3.0	3.5

**Figure 4.45 Delay experience rating distribution for intersections from real-time rides**



## 5 Proposed approach for CLOS assessment

### 5.1 Introduction

This section introduces a proposed approach for applying what we have learnt from this study to CLOS assessments in New Zealand. These recommendations are based, where possible, on the perception rating data collected by this study. Where there are gaps we have supplemented them with professional judgement of the project team and Steering Group, or with external sources of information. For clarity, the tables presented in sections 5.4 to 5.6 provide a description of the source of information used for each CLOS factor and scoring.

Sections 5.2 and 5.3 describe the approach taken to apply study ratings to scores for CLOS factors and outline the use of a workshop to add professional judgement to some of the gaps.

### 5.2 Distribution of cyclist satisfaction ratings

The distribution of ratings on the 1–6 scale by cycle facility type or CLOS factor was used to determine a scoring system using the logic below. Starting from A+, the first condition that is satisfied is the rating for the factor of interest. Where the word ‘and’ is included in a statement both conditions must be satisfied. A total of nine categories are provided, as this satisfied the level of sensitivity required to distinguish between segments that were rated differently by riders.

- A+     $\geq 50\%$  of respondents rated a 6 (ie ‘very satisfied’).
- A      $\geq 50\%$  of respondents rated a 5 or above, and  $\geq 35\%$  of respondents rated a 6.
- B+     $\geq 50\%$  of respondents rated a 5 or above, and  $\geq 15\%$  of respondents rated a 6.
- B      $\geq 50\%$  of respondents rated a 5 or above.
- C+     $\geq 50\%$  of respondents rated a 4 or above, and  $\geq 15\%$  of respondents rated a 5 or above.
- C      $\geq 50\%$  of respondents rated a 4 or above.
- D      $\geq 50\%$  of respondents rated a 3 or above.
- E      $\geq 50\%$  of respondents rated a 2 or above.
- F      $> 50\%$  of respondents rated a 1 (ie ‘very dissatisfied’).

Table 5.1 is an example of the above applied to two different distributions:

**Table 5.1     Example CLOS assessment score using proposed rating methodology**

	Proportion of respondents for each rating						
Distribution	1	2	3	4	5	6	CLOS score
1	1%	2%	10%	20%	31%	36%	A
2	8%	14%	27%	15%	21%	15%	C+

Distribution 1 is scored an ‘A’ as 67% of respondents rated this segment a 5 or above and 36% of respondents rated it a 6. Meanwhile, distribution 2 is scored a ‘C+’ as 50.7% of respondents rated a 4 or above, and 36.1% of respondents rated a 5 or above.

This approach provides a consistent method for scoring CLOS within and between cycle infrastructure types. For example, the overall scores for separated cycle lanes are generally higher than for painted cycle lanes (with some overlap for the 'worst' and 'best' examples of both respectively). This reflects the more favourable perception cyclists have of separated cycle lanes.

## 5.3 Cycling professional workshop

While the distribution of cyclist satisfaction ratings by road network/cycling facility type and CLOS factors was useful, there were gaps in some areas, for example, where we did not have data for a specific factor category such as pedestrian volume. Also, in some cases the distributions were not intuitive. For example, on painted cycle lanes, higher vehicle volume had a rating distribution that appeared to be more positive than lower vehicle volumes.

These issues were not widespread and can largely be explained by small sample sizes and the collinearity between individual factors. That is, a single factor cannot fully explain cyclists' perceptions of CLOS as it interacts with other factors to influence perceptions. For example, the relatively positive rating for high vehicle volumes on painted cycle lanes is likely to be a function of infrastructure quality and not the vehicle volume. On high-volume roads the cycling facilities ridden were generally of superior quality (width, delineation, gap to overtaking vehicles) as existing LOS often align with factors such as vehicle volume.

To account for some of these nuances in the data, a workshop was held with local and national cycling and transport professionals to adjust the scoring methodology where appropriate, and attempt to fill in some gaps that the collected data could not fill.

A core focus of the workshop was to identify interaction terms in the CLOS evaluation framework. The main interactions observed related to path widths and pedestrians for shared pathways, and the interaction of a motor vehicle's overtaking gap with motor vehicle volume and speed for painted cycle lanes and shared roadways. Parked vehicles are also an area of importance for future development.

While the workshop filled several gaps, and in some cases provided a more intuitive scoring system, many gaps remain. This study identified the important influence of driveways and side roads on perceptions of CLOS, particularly for separated facilities. Unfortunately, data for the utilisation of these was not collected, so we cannot fully understand at what increasing level of vehicle movements at driveways and side roads does CLOS decline. This is a focus for future study.

## 5.4 Shared pathway evaluation

### 5.4.1 Single factor ratings for shared pathways

Table 5.1 presents the proposed factors and factor scores for shared pathways. Key features of these facilities are the available space for cyclists and other users, the volume of users across modes, and wider physical and social conditions.

The ratings below consider two-way shared pathways. When considering each factor, the default scenario for the other factors assumes a 3 m path width, cyclist flows of 200 per hour and pedestrian flows of 50 per hour, on level terrain, with no driveways or intersections.

**Table 5.1 Shared pathway factors and rating scale**

Factor	Categories for CLOS	Score	Notes
Two-way effective path width	≥4.00m 3.00–3.99m 2.40–2.99m <2.40m	A B+ C E/F	<p>Effective path width differs from design (or 'edge to edge' width). To calculate effective width based on design width we use the following criteria:</p> <ul style="list-style-type: none"> <li>Obstructions below pedal height reduce effective width by 200 mm.</li> <li>Obstructions above pedal height and below handlebar height reduce effective width by 300 mm.</li> <li>Obstructions above handlebar height reduce effective width by 500 mm.</li> </ul> <p>These distances are for obstructions on one side of the path, repeat calculation for both sides where obstructions are present on shared paths (eg path width reduced by 1 m where there are obstructions above handlebar height on both sides of the path).</p> <p>The scoring system for ≥4 m and 3–3.99 m wide shared paths is derived from the ratings of this study. Given the limited number of narrow paths, and no two-way paths at the smallest width (&lt;2.40 m) professional judgement has been applied to the suggested CLOS scores.</p> <p>Values are based on a cyclist flow of about 200 per hour and pedestrian flow of less than 50 per hour. See section 5.4.2 for interaction terms that include effective path width for shared pathways.</p>
Pedestrian volume (peak hour count both directions)	0–50 per hour 51–100 per hour 101–200 per hour >200 per hour	A B C D	<p>Scoring system for pedestrian volume &lt;100 per hour is derived from rider ratings in this study.</p> <p>Above 100 per hour professional judgement has been used due to low variation in recorded volume on paths studied. Assumes that as pedestrian</p>

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Factor	Categories for CLOS	Score	Notes
			<p>volume increases above a threshold of ~100 per hour CLOS declines markedly.</p> <p>See section 5.4.2 for interaction terms that include pedestrian volume for shared pathways.</p>
Cyclist volume (peak hour count both directions)	<p>0–200 per hour</p> <p>200–500 per hour</p> <p>&gt;500 per hour</p>	<p>A</p> <p>B</p> <p>D</p>	<p>Mix of recorded data, professional judgement and international guidance as the number of cyclists recorded on shared pathways was generally low.</p> <p>Assumes that as cyclist volume increases above 200 per hour CLOS declines markedly.</p>
Uphill gradient	<p>–2.9%</p> <p>3.0–6.9%</p> <p>7.0–9.9%</p> <p>≥10.0%</p>	<p>A</p> <p>B</p> <p>C+</p> <p>C</p>	<p>Scoring system has been assigned using professional judgement and considers the scoring approach by gradient using in Auckland Transport's existing tool.</p> <p>Gradient was not a focus of route selection and so variation is low in the study dataset.</p>
Downhill gradient	<p>–4.9%</p> <p>5.0–9.9%</p> <p>10.0–14.9%</p> <p>≥15.0%</p>	<p>A</p> <p>B</p> <p>C+</p> <p>C</p>	<p>Scoring system has been assigned using professional judgement and considers the scoring approach by gradient using in Auckland Transport's existing tool.</p> <p>Gradient was not a focus of route selection and so variation is low in the study dataset.</p> <p>See section 5.4.2 for interaction terms that include downhill gradient for shared pathways.</p>
Surface quality	<p>Sealed pavement that is well maintained with good drainage.</p> <p>Sealed pavement with good drainage but some defects, some debris likely on path.</p> <p>Unsealed pavement or sealed pavement with significant defects, significant debris likely on path, poor drainage, slippery pavement materials.</p>	<p>A</p> <p>C</p> <p>E</p>	<p>Analysis of surface quality data, both from the instrumented bicycle and rider's ratings, suggests that surface quality is a key determinant of cyclists' perceptions of levels of service.</p> <p>Scoring system has been assigned using professional judgement and considers the scoring approach by gradient using in Auckland Transport's existing tool.</p>



Factor	Categories for CLOS	Score	Notes
Social safety	Frequent sections with human activity, or buildings overlooking path. Good path lighting. Clearly identifiable escape routes.	A	<p>Scoring system has been assigned using professional judgement and considers the scoring approach by gradient using in Auckland Transport's existing tool.</p> <p>Existing approaches such as Crime Prevention Through Environmental Design (CPTED) should guide design.</p>
	Some human activity or buildings overlooking path. Good path lighting. Escape route available.	B	
	No human activity. Path is visually blocked from buildings by walls or vegetation. Adequate path lighting. No escape route available.	C	
	No human activity. Path is visually blocked from buildings by walls or vegetation. No path lighting. No escape route available.	E	

## 5.4.2 Interaction effects for shared pathways

- 1 Effective path width and pedestrian volume: this interaction relates to the availability of space on paths where multiple users must fit within a constrained space. As one would expect, as pedestrian volumes increase, the effective path width must also increase to allow sufficient space for cyclists and pedestrians to travel at different speeds with low conflict. Even at relatively low pedestrian volume a narrow effective shared pathway width can introduce conflict between cyclists and pedestrians and reduce LOS for both modes, not just cyclists.
- 2 Effective path width and cyclist volume: while this study did not record a high number of overtaking or oncoming cyclist interactions, we expect an interaction between effective path width and cyclist volume to influence perceptions of CLOS on shared pathways. The effect may be reduced compared to pedestrian volume, as cyclists travelling in the same direction will interact with each other much less due to similar relative speed. However, many of our shared paths are bi-directional and as cyclist volumes increase the available space must also increase to provide space for all users.
- 3 Downhill gradient and pedestrian volume: downhill slopes increase the relative speed difference between cyclists and pedestrians travelling in the same direction and so can increase the level of conflict between the two user groups.
- 4 The above effects relate to available space and conflict between shared pathway users and so it is likely that a final interaction effect, including pedestrian volume, cyclist volume, effective path width and downhill gradient, could be explored to understand the impact of varying levels of each variable in combination.

## 5.5 Separated cycle lane evaluation

### 5.5.1 Single factor ratings for separated cycle lanes

Table 5.2 presents the proposed factors and factor scores for separated cycle lanes. Of note for separated cycle lanes is the low variability in scores for traffic-related factors. While this does little to differentiate separate facilities from each other, it does provide for comparison with other facility types (eg painted cycle lanes and shared roadways) where separated facilities will score relatively well. Variability in separated cycle lane scoring is driven through other factors including lane width, driveways and side roads, gradient and surface quality.

The ratings in table 5.2 consider a one-way separated cycleway only.

When considering each factor, the default scenario for the other factors assumes a two-way motor vehicle volume of 10,000 per day, one-way cyclist volume of 300 per hour, vehicle speed 50 km/h, and effective cycle lane width of 2.4 m, next to residential land use.

Table 5.2 Separated cycle lane factors and rating scale

Factor	Categories for CLOS	Score	Notes
Vehicle volume (AADT)	$\leq 1,000$ 1,001–2,500 2,501–5,000 5,001–10,000 > 10,000	A+ A+ A+ A+ A	<p>Scoring system by category is based on the facility ratings for this study. The low variation in scores with increasing vehicle volumes reflects cyclists' preferences for separated facilities and the influence of these facilities on good perceptions of LOS at high vehicle traffic volumes.</p> <p>Vehicle volume on the adjacent street/road will drive decision making about providing a separated cycle lane. Thresholds where a facility should become separated need to be established for New Zealand.</p> <p>Peak hour traffic volume is likely to be a better predictor of CLOS; however, we use AADT here to align with the majority of New Zealand cycle network design guidelines. Where peak hour traffic counts indicate a meaningful enough increase in traffic to indicate a shift in score they could be used.</p> <p>See section 5.5.2 for interaction terms that include vehicle volume for separated cycle lanes.</p>
Vehicle speed	$\leq 30$ km/h 31–50 km/h 51–60 km/h > 60 km/h	A+ A+ A+ A	<p>Scoring system by category is based on the facility ratings for this study. The low variation in scores with increasing vehicle speed reflects cyclists' preferences for separated facilities and the influence of these facilities on good perceptions of LOS at higher vehicle traffic speeds.</p> <p>Vehicle speed on the adjacent street/road will drive decision making about providing a separated cycle lane. Thresholds where a facility should become separated need to be established for New Zealand.</p>
Heavy vehicles (count per hour)	TBD	TBD	No scoring system proposed; however, the count of heavy vehicles has previously been identified as potentially having greater importance than percentage of total traffic volume.

Factor	Categories for CLOS	Score	Notes
Effective lane width	$\geq 2.40$ m 2.00–2.39 m 1.40–1.99 m < 1.40 m	A B C D	<p>Scoring system by category is based on the facility ratings for this study. 2.4 m provides for easy side by side riding and overtaking.</p> <p>On separated facilities the separator will reduce the effective width of the cycle lane, higher separators will also require a greater shy distance compared with shorter designs. Further, where vegetation is used on either side of the lane this will reduce the effective lane width as it grows, so regular maintenance of vegetation is important to maintain the LOS. As for shared pathways, to calculate effective path width based on design width:</p> <ul style="list-style-type: none"> <li>Obstructions below pedal height reduce effective width by 200 mm.</li> <li>Obstructions above pedal height and below handlebar height reduce effective width by 300 mm.</li> <li>Obstructions above handlebar height reduce effective width by 500 mm.</li> </ul> <p>These distances are for obstructions on one side of the path, repeat calculation for both sides where obstructions are present, as per shared paths.</p> <p>See section 5.5.2 for interaction terms that include effective lane width for separated cycle lanes.</p>
Cyclist volume (one way)	0–500 per hour 501–1,000 per hour > 1,000 per hour	A B C	<p>Scoring system has been assigned using professional judgement as the number of cyclists recorded on separated cycle lanes was not high enough to affect the level of service.</p> <p>See section 5.5.2 for interaction terms that include cyclist volume for separated cycle lanes.</p>
Buffer between cycle lane and motor vehicle lane	Raised lane (eg at footpath height) Low concrete divider Vertical post/bollard Large physical structure (eg planter boxes)	TBD	<p>No scoring system proposed, as low numbers by separation type for this study make distinction between separators difficult. Further, there are some types of separation in use on the network that were not included in this study, or</p>

Factor	Categories for CLOS	Score	Notes
	Vehicles parked to right of cycle lane		<p>combinations of physical separation (eg low concrete curb with vertical bollards on top).</p> <p>Further research is needed to explore the influence of buffer type on perceived CLOS, and the influence of buffer type on effective width (eg planter boxes with bushes on them may reduce effective width compared with a low concrete curb). Network guidance states that 1.8 m design width is preferred where a buffer such as parked vehicles is used to create a shy distance and maintain 1.5 m effective width.</p>
Commercial driveways crossed by separated cycle lane per 100 m	0 1– 2 ≥3	A B C	<p>Scoring system has been assigned using professional judgement.</p> <p>This study suggests that the most important aspect of driveways and side roads is a vehicle exiting or entering across the path of a cyclist. Use of driveways and side roads is likely to be a function of vehicle volume.</p>
Residential driveways crossed by separated cycle lane per 100 m	No Yes	A B	
Side roads crossed by separated cycle lane per 200 m	0 1 ≥2	A B C	<p>This study did not capture a large enough range of driveway interactions to identify the interaction effect between driveways and side roads on CLOS. Two CLOS effects were identified from this work:</p> <ul style="list-style-type: none"> <li>• The perceived risk/conflict between riders and vehicles where driveways and side roads are present even when no interaction is experienced.</li> <li>• Experienced risk/conflict when a rider and driver interact with each other at a merge point on their journey.</li> </ul> <p>At side roads, different treatments are used where a separated facility stops on entry and resumes on the other side. Research should identify the influence of these.</p> <p>See section 5.5.2 for interaction terms that include driveways and sideroads for separated cycle lanes.</p>

Factors affecting cycling levels of service

Factor	Categories for CLOS	Score	Notes
Uphill gradient	-2.9% 3.0–6.9% 7.0–9.9% ≥10.0%	A B C+ C	Scoring system has been assigned using professional judgement and takes into account the scoring approach by gradient using in Auckland Transport's existing tool.
Downhill gradient	-4.9% 5.0–9.9% 10.0–14.9% ≥15.0%	A B C+ C	Scoring system has been assigned using professional judgement and takes into account the scoring approach by gradient using in Auckland Transport's existing tool.
Surface quality	Sealed pavement that is well maintained with good drainage. Sealed pavement with good drainage but some defects, some debris likely on path. Unsealed pavement or sealed pavement with significant defects, significant debris likely on path, poor drainage, slippery pavement materials.	A C E	Scoring system has been assigned using professional judgement and takes into account the scoring approach by gradient using in Auckland Transport's existing tool. Analysis of surface quality data, both from the instrumented bicycle and rider's ratings, suggests that surface quality is a key determinant of cyclists' perceptions of LOS.
Social safety	Frequent sections with human activity, or buildings overlooking path. Good path lighting. Clearly identifiable escape routes. Some human activity or buildings overlooking path. Good path lighting. Escape route available. No human activity. Path is visually blocked from buildings by walls or vegetation. Adequate path lighting. No escape route available. No human activity. Path is visually blocked from buildings by walls or vegetation. No path lighting. No escape route available.	A B C E	Scoring system has been assigned using professional judgement and takes into account the scoring approach by gradient using in Auckland Transport's existing tool. Existing approaches such as CPTED should guide design.

### 5.5.2 Interaction effects for separated cycle lanes

No interaction effects supported by ratings data were identified for separated cycle lanes for this study; however, the feedback from cyclists on the real-time rides suggested some likely interaction effects that warrant future study:

- 1 Effective lane width and cyclist volume. Overall the volume of cyclists on separated cycle lanes was low. While other users are not supposed to use cycle lanes, where cyclists experience a high volume of other users there is likely to be an interaction between width and cyclist volume.
- 2 We identified that the presence of driveways and side roads crossing the path of riders on separated cycle lanes is important; however, the actual movement of vehicles across the cycle lane is likely the most important influence on perceived CLOS for cyclists. Therefore, an interaction effect between the nature of the driveway (eg residential or commercial) or side road and the vehicle volume on the main road exists. A measure of vehicles per hour crossing the cycle lane per 100 m (or other set distance) is an example of how this could be expressed in terms of the likelihood a given cyclist will encounter a vehicle at a driveway or side road on their ride.

Some driveways will be closer to a side road, for example entrances to off-street parking where many vehicles come and go throughout the day, while others will have lower use comparable to residential driveways.

## 5.6 Painted cycle lane and sealed shoulder evaluation

### 5.6.1 Single factor ratings for painted cycle lanes and sealed shoulders

The default situation for painted cycle lanes is traffic volume of 10,000 vehicles per day, speed limit of 50 km/h.

Table 5.3 presents the factors and factor scores for painted cycle lanes and sealed shoulders (without motor vehicle parking).

Table 5.3 Painted cycle lane and sealed shoulder factors and rating scale

Factor	Categories for CLOS	Score	Notes
Vehicle volume (AADT)	$\leq 5,000$ 5,001–15,000 >15,000	A B C	<p>Scoring system by category is based on the facility ratings for this study, though the value of 'A' (previously B+) has been introduced using professional judgement to highlight the research findings that in the right environment the 'best' painted cycle lanes are perceived favourably by cyclists.</p> <p>Peak hour traffic volume is likely a better predictor of CLOS; however, we use AADT here to align with the majority of New Zealand cycle network design guidelines. Where peak hour traffic counts indicate a meaningful enough increase in traffic to indicate a shift in score they could be used.</p> <p>See section 5.6.2 for interaction terms that include vehicle volume for painted cycle lanes.</p>
Vehicle speed	$\leq 30$ km/h 31–50 km/h 51–60 km/h >60 km/h	A+ B D E/F	<p>Scoring system by category is based on the facility ratings for this study, though again the value of 'A' (previously B+) has been introduced using professional judgement to highlight the research findings that in the right environment the 'best' painted cycle lanes are perceived favourably by cyclists.</p> <p>See section 5.6.2 for interaction terms that include vehicle speed for painted cycle lanes.</p>
Heavy vehicles (count per hour)	TBD	TBD	No scoring system proposed; however, the count of heavy vehicles has previously been identified as potentially having greater importance than percentage of total traffic volume.
Parked vehicles to left of painted cycle lane	TBD	TBD	<p>No scoring system proposed, the influence of parked vehicles to the left of riders on painted cycle lanes and shared roadways requires further study.</p> <p>See section 5.6.2 for interaction terms that include parked vehicles for painted cycle lanes.</p>
Effective lane width	$\geq 1.50$ m 1–1.49 m	A B	Based on distribution of cyclist satisfaction from study rides and supplemented by professional judgement.



Factor	Categories for CLOS	Score	Notes
	0.50–0.99 m 0.20–0.49 m <0.20 m	C E F	<p>Effective lane width for painted cycle lanes is potentially more important and sensitive compared with other facility types where parked cars are adjacent to the lane. Key considerations for painted cycle lane width are:</p> <ul style="list-style-type: none"> <li>Where parked cars are present, effective lane width is typically reduced by ~700 mm.</li> <li>Where parked cars are not present effective lane width reduction to the left of the lane are:               <ul style="list-style-type: none"> <li>obstructions below pedal height reduce design width by 200 mm</li> <li>obstructions above pedal height and below handlebar height reduce design width by 300 mm</li> <li>obstructions above handlebar height reduce design width by 500 mm.</li> </ul> </li> </ul> <p>A painted line separating the cycle lane and vehicle lane has a ~300 mm reduction in effective width to provide a gap between cyclists and overtaking drivers.</p> <p>Therefore, to achieve a 1 m effective lane width on a painted cycle lane with parked cars to the left and no painted buffer between the lane and vehicle traffic a marked lane width of 2 m would be required.</p>
Overtaking gap between cyclist and motor vehicles in adjacent lane	<0.50m 0.50–0.99 m 1.00–1.49 m 1.50–1.99 m ≥2.00 m	D B B+ B+ A	<p>Based on rider gap acceptance recorded from previous minimum overtaking gap study in New Zealand.</p> <p>This study captured data using an instrumentation to measured actual gap widths. This factor needs to be refined to incorporate an element of cycle lane width, buffer width between cycle lane and motor vehicle lane, and the motor vehicle lane width itself.</p> <p>See section 5.6.2 for interaction terms that include overtaking gaps for painted cycle lanes.</p>
Commercial driveways crossing separated cycle lane per 100m	0 1–2	A B	<p>Scoring system has been assigned using professional judgement.</p>

Factor	Categories for CLOS	Score	Notes
	≥3	C	<p>This study suggests that the most important aspect of driveways and side roads is vehicle movements across the path of a cyclist due to these. Utilisation of driveways and side roads is likely a function of vehicle volume.</p> <p>This study did not capture a large enough range of driveway interactions to identify the interaction effect between driveways and side roads on CLOS. Two CLOS effects were identified from this work:</p> <ul style="list-style-type: none"> <li>The perceived risk/conflict between riders and vehicles where driveways and side roads are present even when no interaction is experienced.</li> <li>Experienced risk/conflict when a rider and driver interact with each other at a merge point on their journey.</li> </ul> <p>At side roads, different treatments are used where a separated facility stops on entry and resumes on the other side. Research should identify the influence of these.</p> <p>See section 5.6.2 for interaction terms that include driveways and sideroads for painted cycle lanes.</p>
Residential driveways per 100 m	No Yes	A B	
Side roads to left of cycle lane per 200 m	0 or 1– ≥2	B C	
Uphill gradient	–2.9% 3.0–6.9% 7.0–9.9% ≥10.0%	A B C+ C	Scoring system has been assigned using professional judgement and takes into account the scoring approach by gradient using the Auckland Transport's existing tool.
Downhill gradient	–4.9% 5.0–9.9% 10.0–14.9% ≥15.0%	A B C+ C	
Surface quality	Sealed pavement that is well maintained with good drainage Seale pavement with good drainage but some defects, some debris likely on path	A C	Scoring system has been assigned using professional judgement and takes into account the scoring approach by gradient using in Auckland Transport's existing tool.

Factor	Categories for CLOS	Score	Notes
	Unsealed pavement or sealed pavement with significant defects, significant debris likely on path, poor drainage, slippery pavement materials.	E	Analysis of surface quality data, both from the instrumented bicycle and riders' ratings, suggests that surface quality is a key determinant of cyclists' perceptions of LOS.
Social safety	Frequent sections with human activity, or buildings overlooking path. Good path lighting. Clearly identifiable escape routes.	A	Scoring system has been assigned using professional judgement and takes into account the scoring approach by gradient using in Auckland Transport's existing tool. Existing approaches such as CPTED should guide design.
	Some human activity or buildings overlooking path. Good path lighting. Escape route available.	B	
	No human activity. Path is visually blocked from buildings by walls or vegetation. Adequate path lighting. No escape route available.	C	
	No human activity. Path is visually blocked from buildings by walls or vegetation. No path lighting. No escape route available.	E	

### 5.6.2 Interaction effects for painted cycle lanes and sealed shoulders

- 1 Effective lane width/overtaking gap between cyclists in the painted cycle lane and the volume of overtaking motor vehicle traffic in the adjacent lane, especially heavy vehicles. As mentioned in table 5.3, the gap between cyclists and overtaking vehicles is a function of cycle and vehicle lane widths and any space between the two. On roads with a high motor vehicle volume a larger gap between cyclists and vehicles is preferred.
- 2 Effective lane width/overtaking gap between cyclists in the painted cycle lane and the speed of overtaking motor vehicle traffic in the adjacent lane. As for the interaction term described above, with increasing motor vehicle speeds a larger overtaking gap will improve CLOS.
- 3 An interaction effect between effective lane width/overtaking gap, vehicle volume and vehicle speed should be explored as these three CLOS factors are likely to be highly associated with each other when influencing cyclists' perceptions of CLOS.
- 4 The interaction between parked vehicles, motor vehicle volume and motor vehicle speed should be explored in future work. In urban areas we saw a number of examples of vehicles entering and exiting parking spaces ahead of riders, and vehicles stopping in cycle lanes, all of which contribute to a reduced perception of CLOS among riders.
- 5 As for separated cycle lanes, the presence of driveways and side roads that cross the path of riders on separated cycle lanes is important; however, the actual movement of vehicles across the cycle lane is likely to be the most important influence on perceived CLOS for cyclists.

## 5.7 Shared roadway evaluation

We propose an assessment framework for shared roadways that is largely the same as for painted cycle lanes. This study captured ratings for relatively few shared roadway types and environments, and so the scoring system below is left intentionally blank and requires future research or expert judgement to complete.

Shared roadways will require a unique assessment methodology for each road network type, or will need to include logic that alters scoring and CLOS factors depending on the type of shared roadway selected (eg the bands and scoring for traffic volume will change depending on the shared roadway type).

We note that Auckland Transport's current evaluation methodology includes a 'mixed traffic' worksheet. Though this does not go to the level of detail we propose is needed for the disparate shared roadway layouts currently on the network in New Zealand, the approach may be relevant for some authorities looking to assess parts of their network.

**Table 5.4 Suggested shared roadway CLOS factors**

Factor	Input type	Categories for CLOS
Shared roadway type		Neighbourhood greenway Bus lane Transit lane Shared zone Sealed shoulder with parking Mixed traffic
Vehicle volume (AADT)	Count	≤1,000 1,001–2,500 2,501–5,000

Factor	Input type	Categories for CLOS
		5,001–10,000 > 10,000
Vehicle speed	Km/h	≤30 km/h 31–50 km/h 51–60 km/h >60 km/h
Heavy vehicles (count per hour)	Count	TBD
Parked vehicles to left of painted cycle lane		TBD
Effective lane width	Metres	≥2.50 m 1.50–2.49 m 1.00–1.49 m <1.00 m
Buffer/gap between cyclist and motor vehicles in adjacent lane	Metres	<0.50 m 0.50–0.99 m 1.00–1.49 m 1.50–1.99 m ≥2.00 m
Commercial driveways crossing separated cycle lane per 100 m	Count	0 1–2 ≥3
Residential driveways crossing separated cycle lane per 100 m	Yes/No	Yes No
Side roads to left of cycle lane per 200 m	Count	TBD
Uphill gradient	%	–2.9% 3.0–6.9% 7.0–9.9% ≥10.0%
Downhill gradient	%	–4.9% 5.0–9.9% 10.0–14.9% ≥15.0%
Surface quality	Technical assessment	Sealed pavement that is well maintained with good drainage. Sealed pavement with good drainage but some defects, some debris likely on path. Unsealed pavement or sealed pavement with significant defects, significant debris likely on path, poor drainage, slippery pavement materials.
Social safety	Technical assessment	Frequent sections with human activity, or buildings overlooking path. Good path lighting. Clearly identifiable escape routes. Some human activity or buildings overlooking path. Good path lighting. Escape route available.

Factor	Input type	Categories for CLOS
		No human activity. Path is visually blocked from buildings by walls or vegetation. Adequate path lighting. No escape route available.  No human activity. Path is visually blocked from buildings by walls or vegetation. No path lighting. No escape route available.

### 5.7.1 Interaction effects for shared roadways

Specific interaction effects for shared roadways could not be identified from the data collected for this study; however, we expect similar interactions as seen for painted cycle lanes to be influential for these environments also. Further research is required to understand what interaction effects are, or are not, of interest for specific types of shared roadways, and the nature and magnitude of a given interaction.

## 6 Cyclists' perceptions of environmental factors

There is a range of non-infrastructure related environmental conditions that influence cyclists' willingness to ride. For this study we were interested in the role of weather, hills and the surrounding attractiveness or amenity of the environment. Many of these are elements that cannot practically be removed through design, such as wind and rain, so these factors were not included in the calculations of the final level of service tool. Rather this data was intended to help inform and provide wider context around the frequency and effect of these types of events. Additionally, we split these factors into two groups: 'day-to-day' conditions that cyclists would reasonably expect to encounter on their rides; and more extreme factors that might be experienced less frequently on only a small number of routes, but have a potentially high effect on willingness to ride. Because these extreme events are less frequent, less data is available on them, so this fills a knowledge gap.

Daily weather conditions, hills and the attractiveness/amenity of the surrounding environment may influence cyclists' willingness to ride, as may the route selected for a trip. Survey respondents were asked to identify how each of the following conditions influences their willingness to ride for different cycle trips: 'my commute to and from work or school', 'cycling for sport or exercise', and 'recreational riding and attending social events'.

Given the difficulty of capturing on-road data in a range of environmental conditions and presenting this through video clips in the online survey, a stated preference approach by questionnaire was used to capture the effect of environmental factors on cycling behaviour and willingness to ride. Additionally, as these questions relied on some level of cycling experience, the response rate from beginner riders was so low as to warrant their exclusion from the results presented here.

### 6.1 'Day to day' environmental conditions

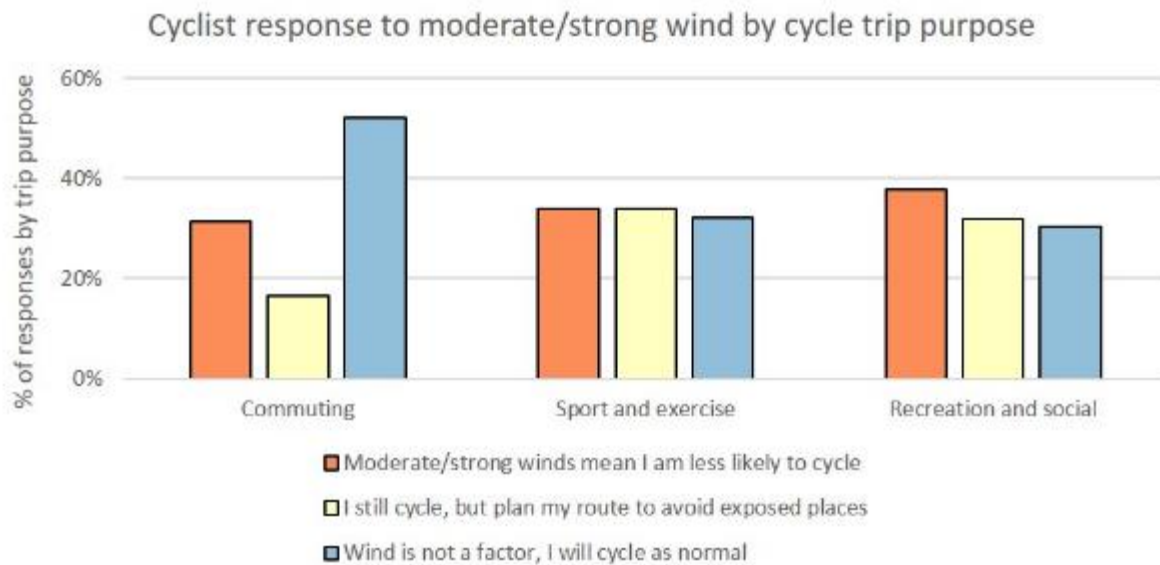
#### 6.1.1 Moderate/strong wind

The influence of moderate/strong wind on willingness to ride varies depending on the nature of a given cycle trip. Commuter trips, compared with sport/exercise and recreation/social trips, show the greatest variation in cyclists' responses, where many commuter cyclists stated that 'wind is not a factor, I will cycle as normal'. Commuter trips also showed the lowest frequency of cyclists who would alter their route based on current wind conditions (figure 6.1).

Sport/exercise and recreation/social trips were more even in the spread of cyclists' responses to moderate/strong wind, though recreation and social trips show some evidence of a slightly higher likelihood of cyclists being less likely to cycle in moderate/strong winds compared with the other trip types.

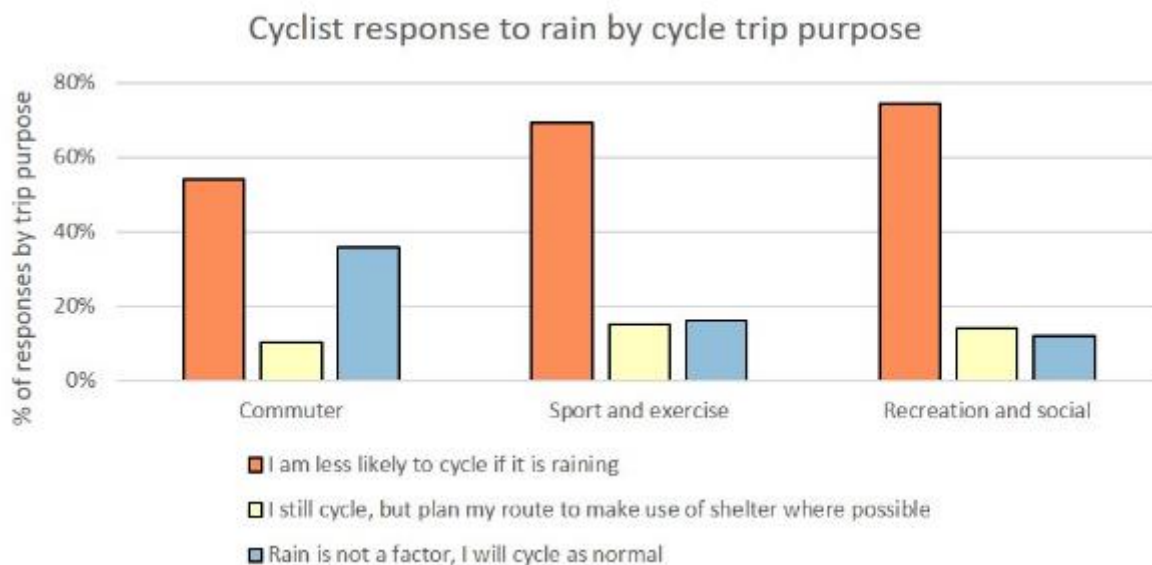
There was a pronounced variation in the influence of moderate/strong wind on cycle trips depending on cyclist experience level. Advanced and expert riders were most likely to state that wind is not a factor and they would cycle as normal, while intermediate cyclists were most likely to not cycle.

Sport/exercise and recreation/social cycle trips show a similar pattern, though both advanced and expert riders were more likely to respond to moderate/strong wind by not cycling or modifying their route than they were for commuter trips.

**Figure 6.1** Influence of moderate/strong wind on cyclists' willingness to ride by trip purpose

### 6.1.2 Rain

Rain had a high level of influence on cycling behaviour for all trip types and was likely to have a negative effect on willingness to ride and prevent a cycle trip from taking place. Commuter cycle trips were less affected than sport/exercise and recreation/social trips, with more cyclists, principally expert cyclists, stating they would cycle no matter what (figure 6.2).

**Figure 6.2** Influence of rain on cyclists' willingness to ride by trip purpose

### 6.1.3 Hills

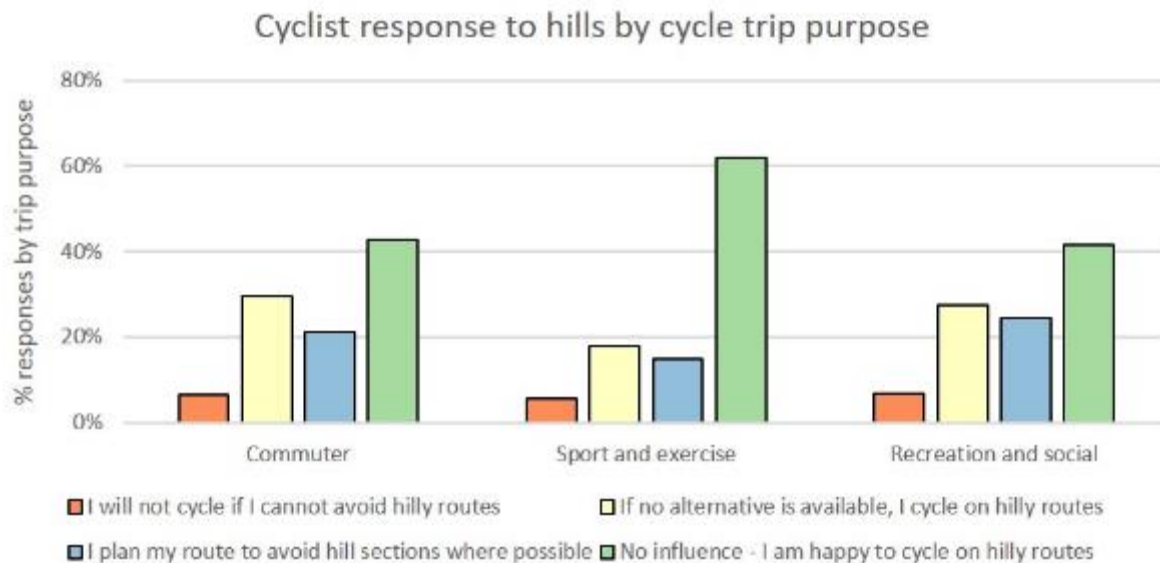
For all cycle trip types more respondents stated they were happy to cycle on hilly routes, or if no alternative was available they would cycle on hilly routes, than those who actively avoided these



environments (figure 6.3). It should be noted that different cyclists have different definitions of a 'hill' – for some this may be rolling hills, while others will think of a winding vertical climb of more than 100 m.

Cyclists' response to hills varied by experience level, with advanced and expert cyclists more likely to cycle as normal compared with intermediate cyclists for all trip types. Of interest is that for sport and exercise trips hills appeared to be 'sought out' by cyclists of all experience levels, though mostly by particularly advanced and expert riders, who stated they were happy to cycle on hilly routes.

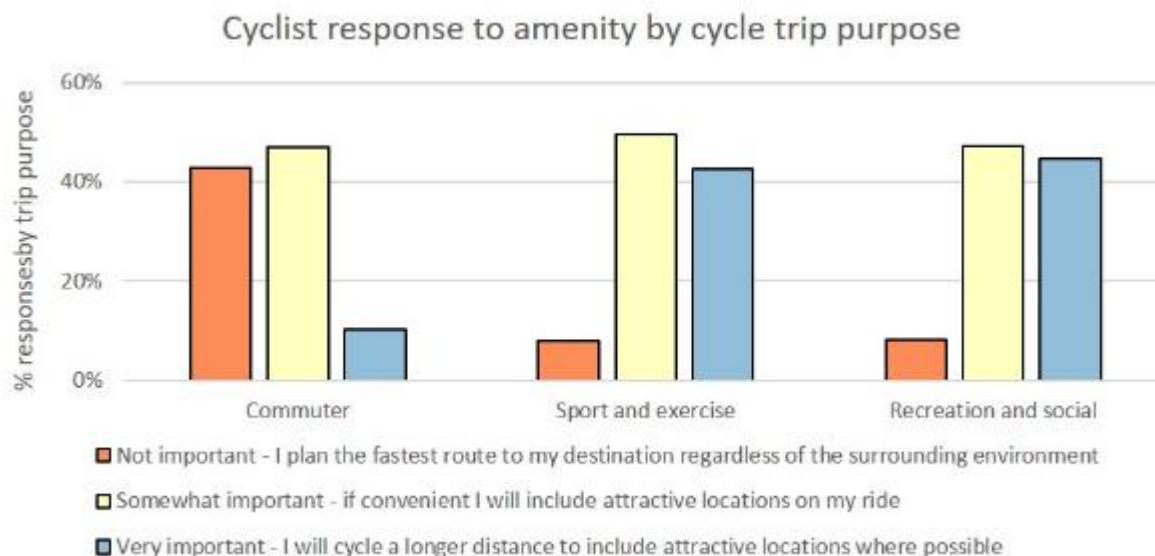
**Figure 6.3** Influence of hills on cyclists' willingness to ride by trip purpose



#### 6.1.4 Attractiveness/amenity

The attractiveness and/or amenity qualities of the surrounding environment were important for cyclists' willingness to ride for sport/exercise and recreation/social trips. This applied for cyclists of all experience levels (figure 6.4). In contrast, these factors were either not or only somewhat important for all riders on commuter trips.

Figure 6.4 Influence of the attractiveness and/or amenity of the surrounding environment on willingness to ride by trip purpose



## 6.2 Moderate to extreme environmental conditions

### 6.2.1 Flooding/inundation

Shallow flooding/inundation, described as 'ankle deep' water, had previously been experienced by two thirds of respondents in the online survey (n=707, 66%) in the past 12 months. Most had experienced these conditions relatively infrequently, less than once a month, and most riders who have encountered shallow flooding were rated as advanced (n=333) or expert (n=246) riders.

Responses to shallow flooding/inundation on a cycle trip were varied, though the most common response was 'not a factor – I will cycle anyway', followed by 'I still cycle but plan my route to avoid exposed/affected places' (figure 6.5). Shallow flooding/inundation appeared to have a lower impact on willingness to ride among advanced and expert riders with many stating they would still ride as normal, or alter their route.

Fewer survey respondents cited experience with deep flooding/inundation, described as 'above your shins', in the last 12 months (n=189, 18%) (figure 6.8). Most (n=156) had experienced these conditions once or twice in the year, with just 10 respondents experiencing deep flooding/inundation once a month or more frequently. Most cyclists who stated they had experienced deep flooding/inundation were advanced or expert riders (n=85 and 78 respectively, 86% of total respondents to question), and no beginner riders responded to this question.

The influence of deep flooding on willingness to ride and trip planning is more pronounced for deep flooding/inundation scenarios compared with shallow events. Deep flooding/inundation was most likely to cause riders of all experience levels to not cycle for a given trip, or to avoid the exposed/affected place (figure 6.5).

Figure 6.5 Self-reported frequency of encountering shallow flooding/inundation by cyclist experience

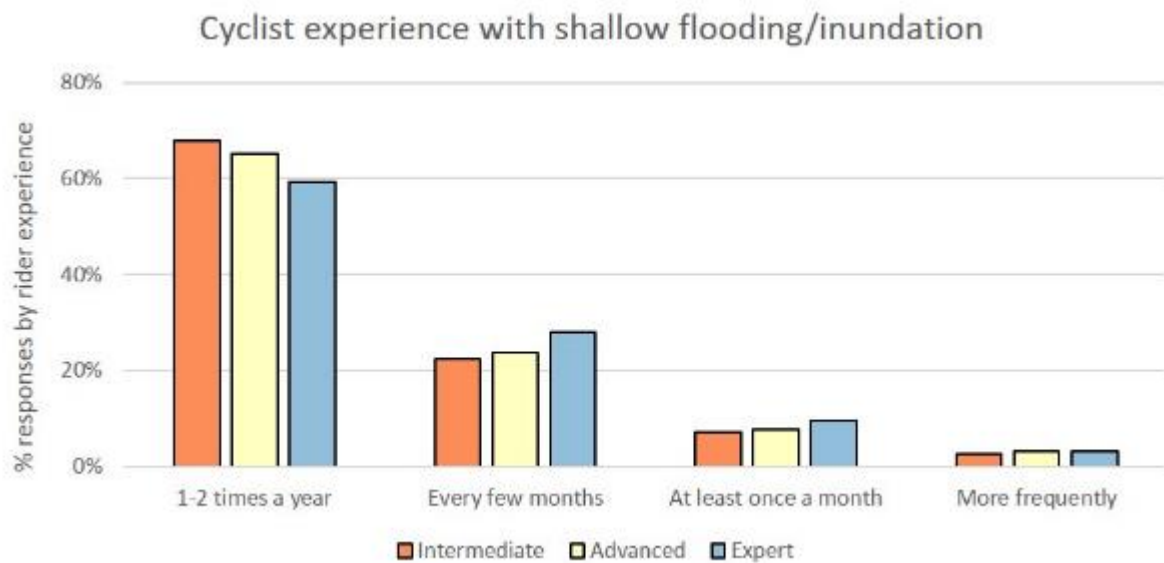


Figure 6.6 Influence of shallow flooding/inundation on willingness to ride by level of cycling experience

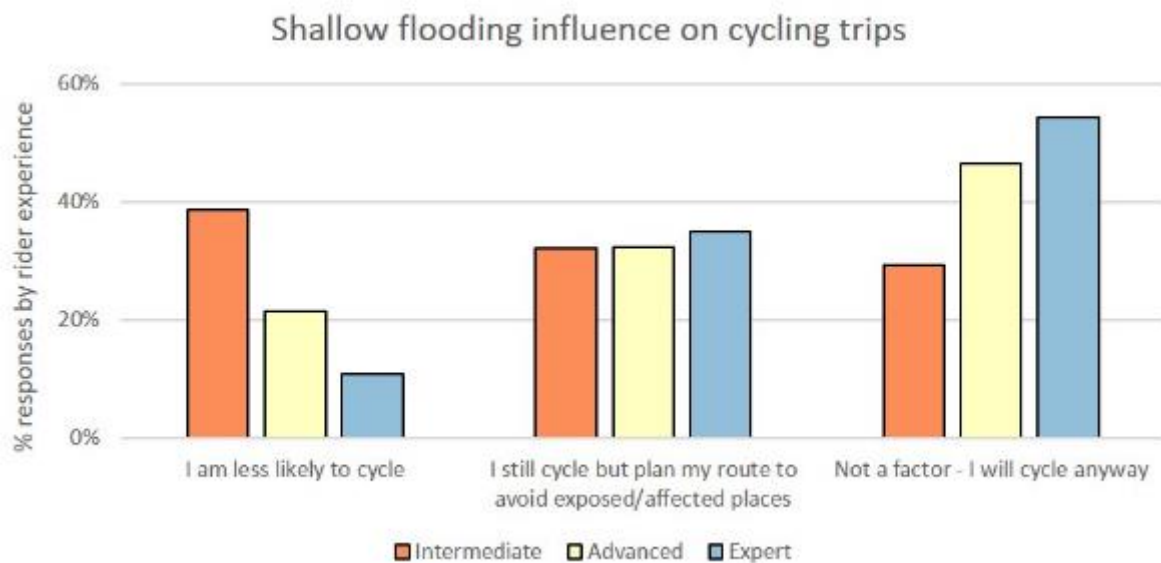


Figure 6.7 Self-reported frequency of encountering deep flooding/inundation by cyclist experience

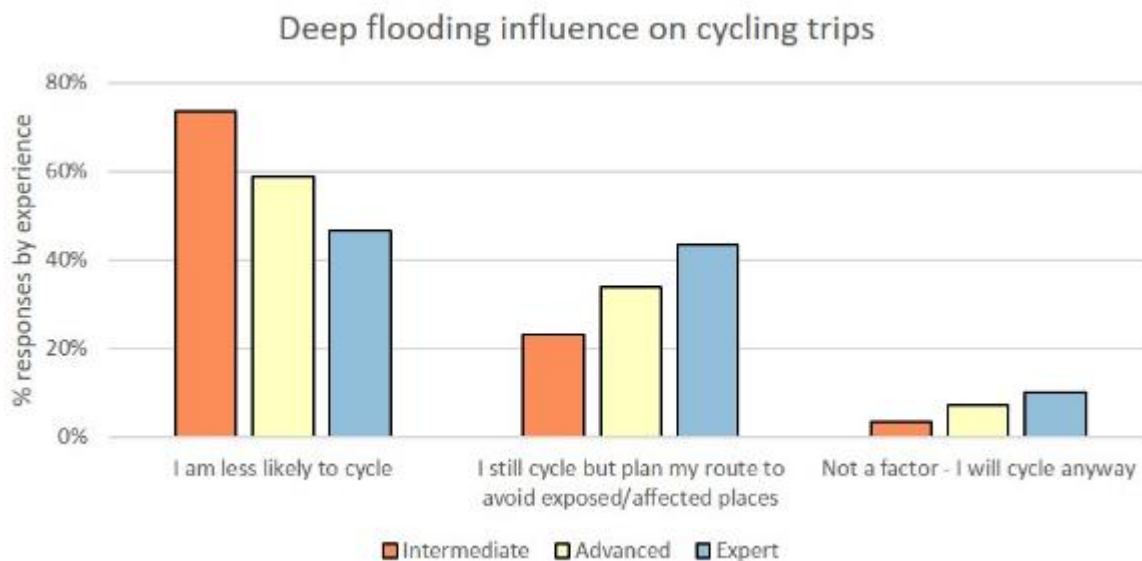
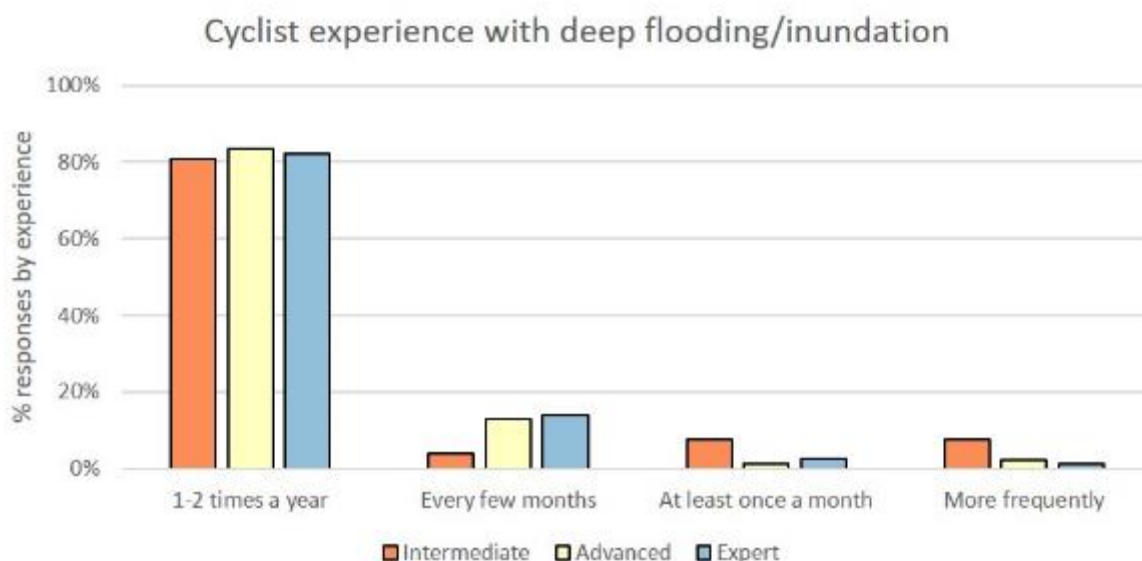


Figure 6.8 Influence of deep flooding/inundation on willingness to ride by level of cycling experience



## 6.3 Sea spray and wave overtopping

Almost half the respondents had experienced sea spray encroaching on their route in the last year (n=490, 46%), which was perhaps a reflection of the large sample population drawn from Wellington, with its many coastal routes. Cyclists reported encountering these conditions relatively infrequently, most just once or twice a year (n=306, 62% of total respondents to this question).

As you would expect, wave overtopping prompted a more pronounced response compared with sea spray, with a greater proportion of riders across all experience levels stating they were less likely to cycle in these conditions. Wave overtopping, like 'deep' flooding, is a fairly extreme environmental impact that

should be mitigated through route selection or design options in places where it occurs with more than minor frequency.

Figure 6.9 Influence of sea spray on willingness to ride by level of cycle experience

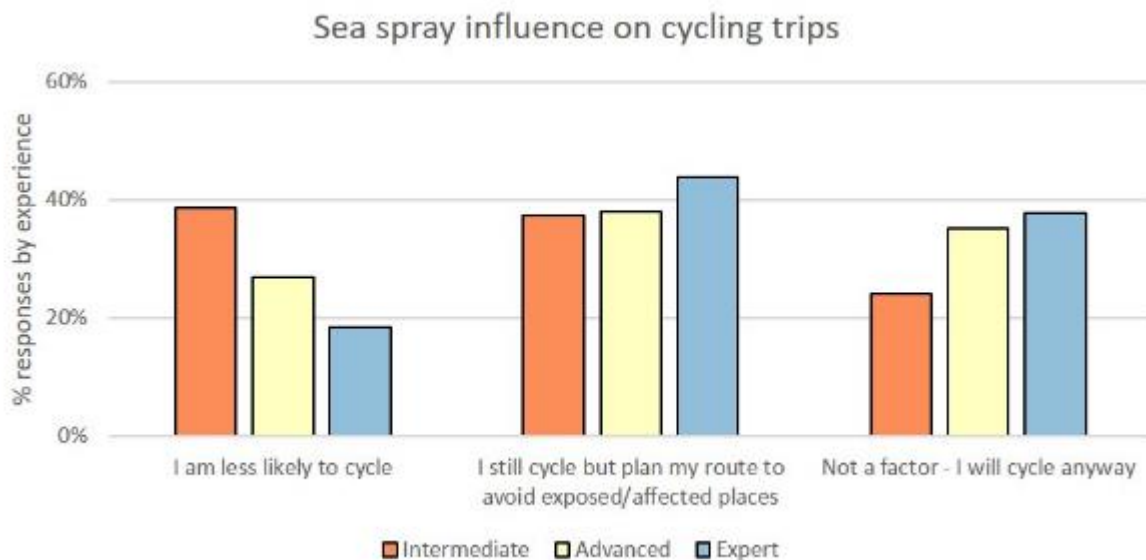
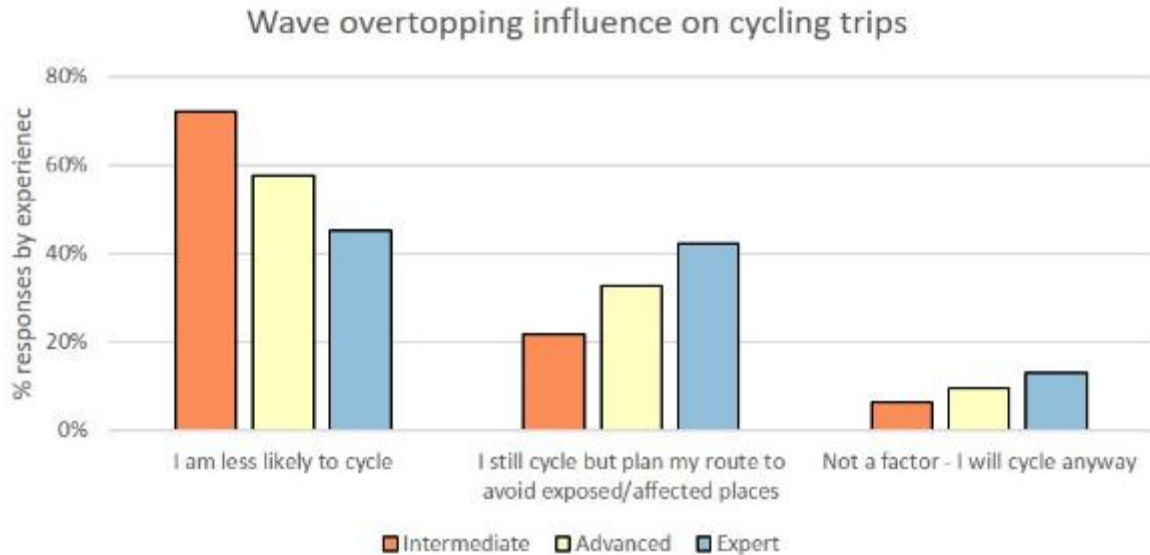


Figure 6.10 Influence of wave overtopping on willingness to ride by level of cycle experience



## 6.4 Summary of environmental factors

The responses to environmental questions from online survey participants were largely intuitive and emphasised the need to consider factors of weather, amenity and terrain at the route selection and planning stage of cycle infrastructure projects.

Ultimately, weather-related impacts such as rain, wind and surface flooding are to be expected on many cycle routes in New Zealand given our climate, and it is impossible to fully mitigate against these effects

along an entire route. Cyclists are adaptive and decisions to cycle will vary day-to-day based on conditions, among other things (eg family and work schedule), while routes will change in response to real-time environmental conditions. Revealed preference data from cyclist counts on existing routes in different common weather conditions is a preferred source of data than stated preference survey data. However, this often misses the purpose of the ride, which as we see from this survey has a bearing on the decision to ride, with commuter trips appearing to be more likely to continue as planned in the face of adverse weather conditions.

Where possible, extreme impacts on infrastructure such as relatively deep flooding, sea spray and wave overtopping should be minimised. However, given the coastal nature of many of our cities and rural cycle routes this will not always be possible and some points on the network will be affected by these conditions. The trade-off is the high amenity values that are often associated with these routes that draw many cyclists when the weather is good. It is likely that efforts to shield infrastructure from the wind and ocean may lead to a reduction in amenity, and not actually draw out more riders during extreme events.

Hills are generally something that cannot be mitigated without taking an alternative route. While hills are likely to be a deterrent to many riders, more experienced cyclists who ride for sport and exercise may seek these locations out to climb. Consideration should be given to the type of rider who is likely to be on these routes and engage with them locally to understand their needs for improved infrastructure. The increase in e-bikes makes it likely that more riders of all experience levels and trip purpose will cycle on hilly routes, so a city like Wellington with many narrow roads on steep hills may see increased interactions between cyclists and drivers.

Incorporating environmental conditions, especially weather effects, into CLOS evaluations alongside infrastructure factors is a challenge. Demand will vary in response to good and adverse conditions at a daily level and by the type of trip purpose, eg calm sunny weather at the weekend is likely to increase recreational riding, while rain on a weekday will decrease commuter trips, but to a lesser extent. However, at an annual level we are less confident in how weather conditions will influence cycling across a city, and we cannot expect to build cycle infrastructure only in places with nice weather. Therefore, infrastructure design should seek to minimise negative effects of environmental conditions where possible, but not seek to remove them altogether.

The proposed assessment methodology in chapter 5 does not incorporate environmental factors into the scoring for a segment. Rather, we include environmental conditions as a discussion point alongside infrastructure level of service variables. For each condition a rating about frequency and magnitude can be selected, so that our expectations for the type of conditions a proposed or current facility is expected or known to be exposed to is clear. Decisions about mitigation, design options and even alternate route selection can be undertaken as necessary to ensure that design options are responsive to external environmental conditions.

## 7 Discussion and recommendations

### 7.1 Cyclists' perceptions of CLOS

This research has captured a range of cyclist perceptions of comfort with cycle facilities, road networks and land use environments in New Zealand. Applied to the question of factors that most influence perceptions of CLOS, the descriptive statistics show there are potentially many variables that do so. Further, we found that individual CLOS factors were unlikely to operate independently of one another. This is to be expected when we consider how cyclists experience the road network and surrounding environment when cycling.

This study built on previous New Zealand research for cyclists' perceptions of CLOS and has added new knowledge of major drivers of perceptions, particularly for non-vehicle influences. We found straightforward evidence that off-road paths and separated cycle lanes were consistently highly rated by cyclists. For each of the facility types studied it was evident there was an interaction between modifiable design elements, and the influence of these on cyclists' interactions with other road or path users. Previous studies have identified interaction effects as they relate to motor vehicles (Jensen 2007 and 2013).

On shared pathways the primary influence of note is cyclist and pedestrian conflict. Here cyclists' preferred environments that did not cause conflict between users, and enjoyed paths that separated cyclists from pedestrians, a view likely shared by pedestrian users also. Features such as path width and downhill gradient can serve to either squeeze cyclists and pedestrians into a more constrained space or increase the relative speed differential between the two modes, and subsequently increase the likelihood of conflict, so decreasing CLOS.

On separated cycle lanes vehicles crossing the path of a rider at driveways and side roads is an important influence. Even where our riders did not encounter a vehicle crossing the lane on their ride the presence of this infrastructure prompted an increased level of discomfort. Further research is needed to understand how different driveway (residential and commercial) and side road layouts influence cyclist perceptions of CLOS, and what volume of vehicle movements, both in and out of driveways/side roads and on the main road, leads to changes in CLOS.

Painted cycle lanes, a common sight on the network, received a wide range of ratings, and while generally rated lower than separated cycle lanes, we saw evidence where very good quality painted cycle lanes in the right locations were perceived well by our riders. Perhaps the biggest driver of ratings for painted cycle lanes is adjoining land use issues – parked cars, driveways and side roads. Carlton Gore Road in Auckland is a good example of a high-quality facility in a location that generates a large number of cyclist and vehicle driver conflicts as cars move in and out of parking spaces and commercial driveways. In contrast, Idris Road in Christchurch, with residential development and occasional parked cars, also built to current standards, rated well despite being on a busy two-lane arterial road carrying around 14,000 vehicles per day, which is over twice the threshold volume at which physical separation is often recommended.

Ultimately, the data and anecdotal feedback around painted cycle lanes suggests they are largely viewed as lower quality environments compared with separated facilities, though survey perceptions ranged as there are some good examples on the network. Some of the riders participating in the field rides stated they actively rode in the lane even when these facilities were present. These riders also felt at risk when cycling beside parked vehicles, including from being hit by drivers opening doors of parked vehicles, from drivers stopping in the lane, and from drivers entering and exiting car parks. This shows the importance

of providing adequate width outside parking spaces (as required by current standards), and also the importance of considering parking occupancy and frequency of turnover.

At intersections, cyclist signal phases were much preferred to all other types. Further, other priority features such as advance stop boxes and coloured surfaces contributed positively to higher cyclist comfort at intersections.

The distribution of rider ratings captured by this study demonstrates a hierarchy of cycling facility types and this is reflected in the suggested CLOS ratings in chapter 5. In doing so we emphasise the benefits gained by providing separation for cyclists especially when attracting new cyclists. We recognise it is not practical to provide physically separated facilities across the network, but think it is important to provide a framework that shows that physically separated facilities maintain a high rating when traffic is busy and fast, and that painted cycle lanes will only rate as highly when traffic conditions and land use is more favourable.

Our research suggests that advanced and expert riders generally rated infrastructure more positively than beginner and intermediate riders (apart from off-road paths). The differences in ratings by experience were more pronounced for the video surveys compared with real-time rides, which were quite small. While the video ratings differed markedly from real-time rides, the comments from riders showed there were factors obvious to them, but difficult to assess from the video clips, eg surface quality, delays, gradient, speed differential relative to vehicles, land use and the spatial dimensions of facilities.

There was, however, little systematic difference between the average ratings for both survey types, and even for beginners the preferred order of facility type was similar to that of more experienced riders. While all riders rated the best facilities in a similar way, less experienced riders were more sensitive to poor facilities and rated them noticeably lower when shown on video. It also appears that less experienced people looking at a facility on video and thinking about cycling on it perceived it to be worse than when they rode it. This raises the question: do we focus on helping their perceptions to become more accurate, or do we overdesign the infrastructure to compensate? Only a small sample of beginner riders participated in the video survey while intermediate riders were well represented in both the real-time and video survey components of the study. Both groups showed a preference for infrastructure that provided some level of physical separation from motor vehicle traffic (shared paths and separated cycle lanes) and at intersections were strongly in favour of signalised intersections that have a cyclist specific phase, and intersections with a separate pedestrian and cyclist crossing point. Because the rating pattern for facility type by rider experience was relatively similar, the use of data from riders with a range of experience levels does not appear to skew the results of a stated preference approach to evaluating cyclists' perceptions of CLOS. Additionally, while we need to consider the heterogeneity of cyclists, as is recommended by previous work (eg Griswold et al 2018), knowing these relative relationships means we can account for this, for example when attempting to attract new cyclists.

An interesting finding from the real-time rides was revealed through statements from a number of expert riders who expressed a preference for riding in mixed traffic environments as opposed to using some of the cycle facilities provided. This included riders who preferred to ride in the motor vehicle lane instead of a painted cycle lane where parked cars were also present, some who would prefer to join traffic at a major intersection instead of using a two-stage crossing to make a right-hand turn, and others who would rather ride with traffic than on a congested shared pathway. Experienced riders, being more confident in traffic, were more likely to interact with traffic to reduce delays on cycling facilities, and also had a better awareness of potential hazards such as parked car doors and unpredictable shared path users, so would ride in traffic to avoid them. Design should not assume that all cyclists will use a separated facility and should therefore aim to ensure that cyclists who choose to remain on the roadway do not have their safety



compromised by not using separated facilities. This might mean providing painted cycle lanes in some locations/streets even where there is an off-road option available.

We do not suggest tailoring design of infrastructure to meet this group's needs, rather it reinforces the need to cater to the 'interested but concerned' or 'intermediate' group of cyclists, as our 'strong and fearless' or expert group are confident making their own judgement on where to ride.

## 7.2 Cyclists' willingness to ride

Respondents to the online survey were asked the yes/no question 'Would you ride here?' for each video. The results for this by facility type were largely intuitive and generally aligned with the hierarchy established by the 1–6 ratings. Overall, for individual segments (see appendix D), respondents were generally quite favourable in their willingness to ride, with over 90% of respondents stating they would be willing to ride on the majority (28 of 39) of segments. Even where mean ratings for specific segments were low, willingness to ride was often quite high. The willingness to ride indicator becomes most useful when these ratings are looked at by experience level and across infrastructure type. This interaction provides useful insights around cycling growth opportunities, current impediments to access for people who ride, and could be used to underpin business cases based on rider intention to use facilities.

Advanced and expert riders rarely stated they would be unwilling to ride in the environments shown in the videos. So, while infrastructure improvements might improve the actual safety of more experienced riders, this would have low influence on frequency or location of travel. The only area where more expert riders would be less willing to ride is on shared paths, where they have to interact with pedestrians and other obstacles (eg bins on rubbish day). Overall advanced riders' willingness to ride on any facility was relatively high no matter the facility type, but they did show a slight preference for separated facilities compared with the other types evaluated.

The data here indicates that about 1 in 10 experienced riders may be motivated to take alternative, shared roadway options on the same route. Therefore, if we are to look at the network as a system, locations with shared path designs could consider also rating the parallel on-road alternative (and choose to calculate a weighted score for this group), eg when looking at the trade-offs between shared and separated facilities. Some advanced and expert riders may not use shared pathways where they are provided, but the number is relatively low compared with the increase in beginner and intermediate riders who are unwilling to ride on painted cycle lanes or shared roadway environments if that is the current situation. As we see in many examples on our networks, where shared pathways are offered some of the more experienced riders will continue to cycle on-road based on their own preferences and decisions on the trade-off for different options. It is important to note that while beginner and intermediate cyclists may enjoy a large increase in comfort if a shared pathway is made available to them, pedestrians who use that space may not have the same perception and will possibly experience a reduction in their own level of service.

For beginner and intermediate cyclists there are many people who would be unwilling to ride on both painted cycle lanes and mixed traffic environments. Given that these are the most common scenarios less experienced riders will encounter on New Zealand's network, and most trips will have at least some time spent on roads with no formal cycling facilities, this is a significant opportunity to increase the uptake of cycling. This is supported by other observational rider studies in New Zealand that have also indicated that riders must divert their ride to a safer route (eg Balanovic et al 2016).

## 7.3 Influence of other transport modes

Travellers in urban areas generally have more than one transport mode available to them, though the quality (actual and perceived) and convenience is likely to vary between modes depending on the time and location of a desired trip. In New Zealand, most urban transport networks have been developed around a car-based model, with just Wellington and Auckland having the population density and size to support well-developed public transport networks with frequent services across their geographies. These two cities are also home to the highest levels of congestion created by car trips, and so would benefit most from an increase in mode shift to active and public transport modes.

Transport demand elasticities have been studied internationally, with consumption of transport influenced in much the same way as other products and services: 'when transport prices decline, mobility tends to increase, and if prices increase, mobility declines' (Litman 2017). Investment in cycle infrastructure is important to create a safer and more attractive environment for cycling, but a shift away from other modes is dependent on other factors.

Policies and costs that discourage car use are considered to be important factors in the decision to cycle, particularly for commuter trips (Wang et al 2011). Parking prices at a destination, fuel costs, and road tolls all influence the cost of travel by private vehicle, and increasing prices sometimes cause shifts to alternative modes such as cycling. The relationship between public transport prices and cycle demand is less clear (Buehler et al 2011). There are many costs associated with private car travel that are not overt and generally not considered by drivers. The Automobile Association in the United Kingdom estimates that vehicle owners underestimate the actual cost of driving by up to half. With costs such as maintenance, insurance, loan repayments, registration and warrants of fitness checks generally not factoring into the perceived cost of daily driving. Further, the time spent in employment each day to cover the costs of running a motor vehicle for the daily commute can be greater than any travel time savings (Montgomery 2013).

There are other non-monetary costs that drive modal choice. In major cities congestion is likely to prompt travellers to consider alternatives to driving, while in less congested towns and cities this is not an issue so incentives to change may be lower. Similarly, even within cities with well-developed public transport and cycle networks, access to these at a household level varies greatly. Further, the influence of trip purpose and destination is highly localised and based on many infrastructure, environment and personal factors

Therefore, it is assumed that as the quality of cycle infrastructure increases, and the relative attractiveness of car use decreases, some travellers will shift modes thus increasing cycling demand. Though it is not a one-to-one transfer, there are other transport modes available to many people such as walking and public transport. Other people may seek to reduce the cost of driving by car-pooling, and others may opt not to travel at all if they can work from home.

The influence of other transport modes on cycling demand is not directly explored in the surveys of this research, as the sample recruited were mostly already frequent riders and therefore have different 'tipping points' to people who predominantly drive.

## 7.4 Comparison of on-road and online survey approaches

This study made use of cyclists' perceptions of CLOS captured during on-road rides of set routes in real time, and from a large sample of online survey respondents who viewed short video clips captured during those rides.

This study, alongside capturing valuable datasets relating to cyclists' perceptions of CLOS in New Zealand that will have broader value, has contributed to an evaluation of alternate methodologies for capturing this type of information. We hope this commentary will inform future studies in overseas locations where researchers are interested in undertaking their own localised research.

As expected, a much richer dataset could be collected from the on-road riders, with comments provided at each stop along their ride and infrastructure being rated across multiple scales in near-to-real-time. There is evidence in this study of variation between ratings in the real-time and video survey responses; however, perhaps the largest difference is the contextual feedback that can be gleaned from real-time riders to understand what is driving them to make a good or poor rating. For example, the interaction of path width and downhill gradient with pedestrian volumes on shared pathways comes through strongly from our real-time rider comments and it is a major driver of their ratings. Conversely, while the video survey included clips with varying pedestrian levels, on different path widths, and on downhill, flat and uphill segments, it is difficult to understand how much of the respondent rating is merely the response to the most visible element of the video – the pedestrians – or if they are considering the influence of all these factors like our real-time riders. Some of this could be alleviated by delivering videos in a controlled environment and seeking comment from participants, the trade-off being a small sample size and increased level of research team resources. We note that Griswold et al (2018) have combined these two approaches, delivering the same survey online and in-person, with the qualitative questions 'Why?' and 'What would improve it?' added to the in-person study component.

The benefit of the online approach that complemented the on-road rides was the ability to capture a larger sample, which also overcame some of the health and safety issues in capturing attitudes of beginner riders in different environments. Also, the experimental control provided in the ratings, where segments can be randomised in order (ie riders are rating that segment and are not influenced by the immediately preceding segment on that route). However, the online survey used video footage captured during the on-road rides, which for logistical purposes were all designed as loops to return riders to the research team. Within each loop there was variation in midblock and intersection typologies, though this was limited as discussed in chapter 3. Overseas studies, such as Jensen (2007; 2013), opted not to use volunteer riders to capture video footage, and instead captured video footage at many different midblocks and intersections. This approach meant that the study could be designed backward from the modelling needs to ensure that the video footage was captured across a wide enough range of infrastructures, and that there was sufficient variation in the final models.

On reflection, while the use of an instrumented bike to capture data during rides was a novel approach to comparing CLOS perceptions with real-world conditions, there was a trade-off with sample size. Additionally, the resources required to transport the bikes around the country and the need to have technical staff on-site supporting the instrumented bikes was large in terms of both time and cost. This was prototype instrumentation, but as instrumentation becomes easier to add, calibrate and remove this may become less of a barrier. Bezuidenhout et al (2005) captured perceptions of CLOS without using instrumented bikes, and instead opted for a larger sample of riders on each route riding their own bikes and filling out surveys. This approach gives an opportunity to obtain perceptions from a much larger group of people, the trade-off being no data from the instrumented bike to compare perceptions against real-time traffic conditions.

As previously noted, the real-time ride component of this study involved a relatively high proportion of males (46 vs 17, or 73% vs 27%). We also see, both in this study and previous work, that female ratings can be quite different from males'. We attempted to address this imbalance ahead of the volunteer rides, but ultimately the much larger expression of interest and availability to ride on the selected days resulted in more men than women riding. Because just 63 riders rode the six routes, the low proportion of females

also resulted in a low actual number of riders. For the video survey, 40% of respondents were female, but given the large number of respondents this was less of a problem as there was still a large number of responses to analyse. The challenge of recruiting female riders for real-time rides should be identified early in the recruitment process for future work.

## 7.5 Validation and continued development of CLOS assessment in New Zealand

The CLOS assessment approach introduced in chapter 5 takes a ‘scoring’ approach. Doing so helps to ensure the methodology is accessible, transparent and users can see exactly what factors and their values are contributing to the overall segment score. Anecdotally a lot of investment is occurring without use of a CLOS evaluation tool, so having a consistent, user-friendly, agreed approach is critical to optimise our investment decision making. It is also modifiable, with the ability to be updated over time with the inclusion of new or varied factors, and an updated scoring system as new learnings are gained.

This approach has been developed as a research output based on data collected from a relatively small sample of routes in New Zealand. It has been refined through expert inputs to ensure it can be practically applied by planners and designers of cycling infrastructure. For practicality, it closely aligns with existing user-friendly practitioner processes (eg Auckland Transport 2018).

There is a need to further validate the effectiveness and usefulness of the proposed assessment approach through use on cycle infrastructure design and decision making in a broad range of New Zealand contexts by practitioners. Further, learnings from different users’ and organisations’ use of the tool must be captured and used to update the tool over time. WSP Opus are currently applying this approach to a real-world cycling environment in New Zealand to understand how the tool is rating infrastructure we are familiar with, and using our learnings to further refine the methodology.

Any future New Zealand CLOS evaluation tool will require some centralised oversight and ownership, probably best placed within the Transport Agency. In this leading role, the Transport Agency can communicate with local authorities who are undertaking CLOS assessments of future or existing infrastructure to understand how the tool is being used by different organisations and collate feedback in one place for any necessary updates.

## 7.6 Perceptions of CLOS at a route level

This study examined perceptions of CLOS for midblock and intersection segments in isolation and did not attempt to understand perceptions of transitions between segments or across an entire route. It was evident from the routes ridden across all three cities that in the space of a relatively short 40-minute ride that cyclists navigate a wide variety of infrastructure types with varying quality of transitions between them.

The assessment methodology proposed in chapter 5, like most comparable approaches, is designed to rate a route by individual midblock segments each with their own score. As a result, it provides users with insight into how segments of a route might be perceived by cyclists, but not how the route is performing overall. It is possible that each segment rates highly, but that across the route diverse types of infrastructure and facilities mean the overarching journey experience is poor.

Future research should consider how the cohesiveness of infrastructure, or lack of, influences cyclists’ perceptions of comfort while cycling in New Zealand. This is likely to be best achieved through in-depth

on-road studies, where many riders can cycle set routes across the country and provide during and post-ride feedback on their experience.

## 7.7 Limitations

The primary limitation of this study was the route selection and low variation of traffic conditions. In trying to capture data from many cycling facilities, road network environments, traffic conditions and intersections we have a dataset that is very broad, but not very deep in some places. Further, while the instrumented bikes provided accurate data collection regarding cycle interactions with vehicles, we were limited to having just two riders out on the network at once. Because of this it took a full day (7 am to 4.30 pm) of riding each route to get through approximately 10 riders, with the 63 on-road rides reflecting six full days of data collection. This approach meant that some types of infrastructure were only ridden by 10 people as it was present on only one of the six routes.

The expectation from this study's methodology was that by riding the same routes 10 times across a day riders would experience different traffic conditions and that the effect of traffic could be well understood. Unfortunately, our riders experienced low variation in traffic conditions, with many not being overtaken by any vehicles on the specific segments that were of interest to us. This meant that the collection of traffic volume, speed and overtaking gap data from the instrumented bicycles was not as useful as expected. The research collected a good set of information about cyclist perceptions where there is no or low traffic encounters, but future data collection should specifically target rides in busier traffic conditions.

These two methodological components both impacted on the analysis that could be undertaken for the study. The route selection process did not allow for a study design that ensured all independent CLOS factors were uncorrelated (orthogonality), and the real-time data collection approach did not provide the expected variation in the dataset. Because CLOS evaluation is a breakdown of a space or segment of the network into many individual components that are in fact not independent of each other (eg a cyclist does not experience the width of a lane and the volume of overtaking vehicle traffic independently as they ride) there is a high degree of correlation between variables in a predictive CLOS model.

For our analysis this means that any predictive modelling is likely to experience limitations of multicollinearity. Multicollinearity occurs where one, or more, predictor variables in a model can be predicted by other variables with a substantial degree of accuracy. For a study of this nature, where many of the CLOS factors are categorical, the limitation is enhanced. As there is a limited range of values for each factor, and constraints around the number of different intersections and midblock segments that could be recorded for the purposes of this study, the amount of variability in the predictor variables in the model is relatively low. These limitations may hide statistically significant variables and may even cause the signs of coefficients to switch.

One option to reduce multicollinearity is to design the data collection itself to try and achieve an orthogonal study design. This was considered; however, it is likely that only a very small number of variables would be included in a model, and it would be impossible to understand to what degree these individual factors were a proxy for others. For example, it is likely that the separation a cyclist has from traffic, the traffic volume, and the speed of traffic are highly colinear, so we may look to include just one factor to reduce bias. The question arises, which factor should we retain, and to what degree does the selected factor predict cyclists' perceptions, or is it simply a proxy for other factors not explicitly included in a predictive model?

The decision to select routes that would capture data for a wide range of infrastructure, environmental and motor vehicle variables, as opposed to working backwards from the needs of a predictive model

meant that the required orthogonality and variation was not achieved. Because of this, the original intention to undertake statistical predictive modelling, akin to Jensen's 2007 and 2013 studies, proved impractical and so we relied on non-statistical approaches to assign relative CLOS scores to single factors across different cycle facility and road network types, based on an expert assessment of the data points and rider comments. This is a limitation in terms of our ability to create a predictive model but was a trade-off to capture a dataset that was broader than it would otherwise have been.

Our findings for shared roadway environments are incomplete due to low variation in different facilities cycled across the six routes. Shared roadways include neighbourhood greenways, bus lanes, transit lanes, shared roadways and mixed traffic environments. Within each of these network types there is a range of designs currently in operation on the national network that make it difficult to assume that the small number of shared roadways cycled for this study are reflective of all other facilities. As such, we have opted not to provide a rating methodology for shared roadways and suggest that a future study should focus exclusively on these road environments, or at a minimum seek to understand at what point does CLOS become so low that a painted or separated facility must be considered. There are many new neighbourhood greenway environments currently being installed in Christchurch with reduced vehicle speeds, which will provide an interesting case study location to understand cyclist perceptions of the infrastructure, and motor vehicle drivers' responses to the layout.

For shared paths our study is expected to be a better estimate of comfort for commuter or public transport type paths (those whose function is to move people from A to B), and that shared paths, or perhaps more accurately shared spaces, like the Wellington waterfront are a different facility type altogether. In these spaces amenity and environmental factors may be more important than some design treatments and interactions with other users.

Further, a facility may change in function throughout the day – during the morning and afternoon commuter period a shared path or cycle lane might cater mostly to commuters, and at other times be used more for recreational trips. Therefore, CLOS varies across the day for the same facility. While our study rode the routes at various times of day, the motivation to ride was the same for each rider – study participation. To better explore the difference in perception between commuter and recreational riders an intercept study of individuals on a route may be a potential method to capture ratings from a range of cyclists for different trip purposes.

## 7.8 Recommendations

To build on the baseline findings and methodology established here, we recommend considering the following actions:

- 1 Fill critical gaps in our understanding of cyclists' perceptions of cycling infrastructure, including:
  - a Analysis and integration of other New Zealand datasets that will complement the analyses presented here and improve the evaluation of cycling infrastructure, especially considering data collected by studies such as the previous 'Cycle for science' study (Bezuidenhout et al 2005) which used a similar rating scale applied here.
  - b Research that controls for traffic conditions on different cycling infrastructure and road network types to allow for more comprehensive quantitative analysis of motor vehicle influences on perceived CLOS, including interactions with modifiable infrastructure design elements.
  - c Further research of how interruptions to paths and lanes influence perceptions of CLOS, including a better understanding of residential and commercial driveways and side roads. Of interest for this

work is the interplay between frequency of interruption (eg number of driveways per x distance), and the utilisation of these interruptions (eg number of vehicle movements per driveway/side road per hour/day), and the modifiable design elements that may be implemented to minimise disruption. It is likely that driveway and side road factors interact with motor vehicle volume and so an additional interaction term should be included in a New Zealand CLOS evaluation tool if proven.

- d Study of shared roadway environments that were under-represented in this research. As a minimum we recommend research that identifies a threshold limit where motor vehicle volumes are at a point where separation should be introduced. This work will also identify the interaction between vehicle volume, vehicle speed and overtaking buffer/gap on perceptions of CLOS for shared roadways.
  - e Gather more perceptions of people who do not currently ride but may consider doing so in future.
- 2 Develop and validate the effectiveness and usefulness of the proposed assessment approach by testing it on 'real-world' cycling infrastructure design, evaluation and decision-making processes including:
- a Comparison of the scoring methodology with existing local approaches to evaluating CLOS
  - b Review of the proposed interaction effects for different cycling infrastructures at a local level
  - c Ongoing evaluation of the CLOS factors included in the assessment and the scoring system used
  - d Identify opportunities to build on a segment-based evaluation to better assess route or area level CLOS, an approach not investigated by this research.

## 8 References

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## Appendix A: CLOS frameworks

Table A.1 LOS metrics for network operations planning

CLOS needs	CLOS measure	Rating	Service measure values
Mobility	Travel speed	A-B	<ul style="list-style-type: none"> <li>High quality, high priority links which permit quick, unhindered travel by bicycle</li> <li>Typical cyclist operating speeds are largely unconstrained (eg can travel at speeds greater than 25 km/h)</li> <li>No or minimal delay at intersections (eg grade separated crossing or at grade crossing of minor local road)</li> </ul>
		C-D	<ul style="list-style-type: none"> <li>High quality routes with seamless connections that permit somewhat unhindered travel by bicycle</li> <li>Typical cyclist operating speeds are somewhat constrained (eg cyclist limited to a speed range from 20 to 25 km/h)</li> <li>Some delay at intersections (eg at-grade crossing of collector road or minor arterial; short signal phase at signalised intersections or cyclists rarely made to wait a full cycle based on arrival)</li> </ul>
		E-F	<ul style="list-style-type: none"> <li>Low speed, shared environment which permits only hindered travel by bicycle</li> <li>Typical cyclist operating speeds are constrained (eg cyclist speed less than 20 km/h)</li> <li>Significant delay at intersection (eg at-grade crossing of busy arterial road and therefore gap times are long; cyclists likely to wait a full cycle based on arrival)</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>
	Congestion	A-B	<ul style="list-style-type: none"> <li>Cyclists are unimpeded or only slightly restricted to choose their speed</li> </ul>
		C-D	<ul style="list-style-type: none"> <li>Cyclists are somewhat impeded in their choice of speed</li> </ul>
		E-F	<ul style="list-style-type: none"> <li>Cyclists are restricted and their choice of speed is dictated by others</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>
	Grades	A-B	<ul style="list-style-type: none"> <li>Flat grades (eg 0 to 2%)</li> </ul>
		C-D	<ul style="list-style-type: none"> <li>Flat to steep grades (eg 2 to 5%)</li> </ul>
		E-F	<ul style="list-style-type: none"> <li>Steep grades; steps or stairs (eg &gt;5% sustained for 50 to 100 m)</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>
Safety	Risk of cycle-to-cycle/pedestrian crash	A-B	<ul style="list-style-type: none"> <li>No to limited risk</li> <li>Good line of sight</li> <li>Speed differential low (eg similar cyclist type such as all recreational cyclists)</li> </ul>

Appendix A: CLOS framework

CLOS needs	CLOS measure	Rating	Service measure values
		C–D	<ul style="list-style-type: none"> <li>• Medium risk, some platooning of cyclists and cyclists slowing down for pedestrians</li> <li>• Good to fair line of sight</li> <li>• Speed differential medium (eg some mixture in cyclist type such as predominantly recreational cyclists with some commuter cyclists)</li> </ul>
		E–F	<ul style="list-style-type: none"> <li>• High risk, crashes can result in several upstream cyclists to brake abruptly or crash</li> <li>• Poor line of sight (eg blind curves)</li> <li>• Speed differential high (eg mixture in cyclist type such as recreational cyclists combined with family cyclists, commuter cyclist and training cyclists)</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>• N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>
	Risk of crash caused by surface unevenness or slippage	A–B	<ul style="list-style-type: none"> <li>• Sealed pavement that is well maintained with good drainage</li> </ul>
		C–D	<ul style="list-style-type: none"> <li>• Sealed pavement with good drainage but some defects</li> <li>• Some debris on path</li> </ul>
		E–F	<ul style="list-style-type: none"> <li>• Unsealed pavement or sealed pavement with significant defects</li> <li>• Significant debris on path</li> <li>• Poor drainage</li> <li>• Significant slippery pavement materials (eg tram rails or road markings)</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>• N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>
	Risk of crash with stationary hazards	A–B	<ul style="list-style-type: none"> <li>• No or limited stationary hazards on the path and adjacent to the path (eg well clear of street furniture (poles, seats, bins), trees, garbage, parked cars)</li> </ul>
		C–D	<ul style="list-style-type: none"> <li>• Occasional or a low density of stationary hazards on the path or adjacent to the path (eg parked cars that are frequently accessed such as in strip shopping centres, street furniture (poles, seats, bins), trees, garbage)</li> <li>• Occasional parked cars or cars coming off parking that can block or hinder the natural path of cyclists</li> </ul>
		E–F	<ul style="list-style-type: none"> <li>• Frequent or a high density of stationary hazards on the path or adjacent to the path (eg parked cars that are frequently accessed such as in strip shopping centres, street furniture (poles, seats, bins), trees, garbage)</li> <li>• Frequent parked cars or cars coming off parking that can block or hinder the natural path of cyclists</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>• N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>
		A	<ul style="list-style-type: none"> <li>• Exclusive bicycle facility in a low-risk road environment</li> </ul>
		B	<ul style="list-style-type: none"> <li>• Exclusive bicycle facility in a low- to medium-risk road environment or no bicycle facility in a low-risk road</li> </ul>

CLOS needs	CLoS measure	Rating	Service measure values
	Risk of cycle-to-motor vehicle crash at midblocks		environment
		C	<ul style="list-style-type: none"> <li>Exclusive bicycle facility in a medium to high risk road environment or no bicycle facility in a low- to medium-risk road environment</li> </ul>
		D	<ul style="list-style-type: none"> <li>Exclusive bicycle facility in a medium to high risk road environment or no bicycle facility in a medium risk road environment</li> </ul>
		E	<ul style="list-style-type: none"> <li>Bicycle lane only (not Copenhagen style facility where the bicycle facility is behind a kerb) in a high-risk road environment or no bicycle facility in a medium to high-risk road environment</li> </ul>
		F	<ul style="list-style-type: none"> <li>No bicycle facility in a high-risk road environment</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>
	Risk of cycle-to-motor vehicle crash at intersections and/or driveways	A	<ul style="list-style-type: none"> <li>No crossings of motor vehicles or fully separated crossings (including no or limited driveways)</li> <li>Fully controlled crossings of motor vehicles at low- to medium-volume roads, without concurrent movements (eg exclusive bicycle movement)</li> </ul>
		B	<ul style="list-style-type: none"> <li>Crossings limited to driveway crossing only</li> </ul>
		C	<ul style="list-style-type: none"> <li>Uncontrolled motor vehicle crossings at low-volume, low-speed roads (eg give way or roundabout residential street intersection)</li> <li>Fully controlled crossings of motor vehicles at high- volume roads, without concurrent movements (eg exclusive bicycle movement)</li> <li>Signalised intersection with high volumes, large numbers of cyclists on the through movement but fully controlled right turns</li> </ul>
		D	<ul style="list-style-type: none"> <li>Uncontrolled motor vehicle crossing at medium-volume, medium-speed roads (eg give way or roundabout collector, sub-arterial road intersection)</li> <li>Fully controlled crossings of motor vehicles at medium-volume roads, with concurrent movements (eg no exclusive bicycle movement)</li> <li>Signalised intersection with high volumes, large numbers of cyclists on the through movement and filtered right turns</li> </ul>
		E	<ul style="list-style-type: none"> <li>Uncontrolled motor vehicle crossing at medium- to high-volume roads (eg non signalised arterial road intersection)</li> </ul>
		F	<ul style="list-style-type: none"> <li>Uncontrolled motor vehicles at high-volume, high-speed intersecting roads (eg non-signalised arterial road intersection)</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>

Appendix A: CLOS framework

CLOS needs	CLOS measure	Rating	Service measure values
Access	Access to and ability to park close to destination	A	<ul style="list-style-type: none"> <li>Proper bicycle parking facilities are readily available immediately adjacent to key destinations and can be accessed directly from the bicycle network. Parking is suitable for likely trip purpose (racks for occasional or short-term users, secure cages/lockers for regular or long-term users)</li> </ul>
		B	<ul style="list-style-type: none"> <li>Proper bicycle parking facilities are readily available within close walking distance to key destinations and can be accessed directly from the bicycle network. Parking is suitable for likely trip purpose</li> </ul>
		C	<ul style="list-style-type: none"> <li>Proper bicycle parking facilities are readily available within a moderate walking distance to key destinations and can be accessed directly from the bicycle network</li> </ul>
		D	<ul style="list-style-type: none"> <li>Proper bicycle parking facilities are somewhat available within a moderate walking distance to key destinations, or parking at or near a location is located a moderate walking distance from the bicycle network</li> </ul>
		E	<ul style="list-style-type: none"> <li>Proper bicycle parking facilities are somewhat available within a long walking distance to key destinations, or parking at or near a location is located a long walking distance from the bicycle network</li> </ul>
		F	<ul style="list-style-type: none"> <li>Proper bicycle parking facilities are not available</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>
	Suitability	A	<ul style="list-style-type: none"> <li>Cycling highly suitable as follows: <ul style="list-style-type: none"> <li>off-road facility for use by bicycles only (eg off-road bicycle only path)</li> </ul> </li> </ul>
		B	<ul style="list-style-type: none"> <li>Cycling suitable as follows: <ul style="list-style-type: none"> <li>off-road shared-use path with low pedestrian numbers</li> <li>on-road bicycle lane separated from car parking or road shoulder with no car parking on a low-volume road</li> <li>on-road shared-traffic environment marked on a low-speed and low-volume road</li> </ul> </li> </ul>
		C	<ul style="list-style-type: none"> <li>Cycling moderately suitable as follows: <ul style="list-style-type: none"> <li>off-road shared-use path with medium pedestrian numbers</li> <li>on-road bicycle lane shared with minimal car parking or road shoulder with minimal car parking on a low-volume road</li> <li>on-road shared-traffic environment on medium-volume road and low speed road</li> </ul> </li> </ul>
		D	<ul style="list-style-type: none"> <li>Cycling moderately unsuitable as follows: <ul style="list-style-type: none"> <li>off-road shared-use path/zone with high pedestrian numbers or speed restrictions (eg 10 km/h)</li> </ul> </li> <li>on-road bicycle lane or road shoulder on high-volume road</li> </ul>

CLOS needs	CLoS measure	Rating	Service measure values
			<ul style="list-style-type: none"> <li>on-road shared-traffic environment on medium to high volume or medium to high speed road</li> </ul>
		E	<ul style="list-style-type: none"> <li>Cycling unsuitable as follows: <ul style="list-style-type: none"> <li>cycling significantly impeded due to physical obstructions that require getting off the bike (eg stairs)</li> <li>cycling is unsuitable due to inadequate separation from traffic that is either high speed or high volume</li> </ul> </li> </ul>
		F	<ul style="list-style-type: none"> <li>Cycling highly unsuitable or prohibited</li> <li>Cycling prohibited</li> <li>Cycling is unsuitable due to inadequate separation from traffic that is both high speed and high volume</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>
Information	Traveller information available, including signposting	A–B	<ul style="list-style-type: none"> <li>Complete and clear signposting with routes and distances is fully available (with consideration to the nature of cyclists and the area, eg a tourist area would require more information than a local neighbourhood)</li> </ul>
		C–D	<ul style="list-style-type: none"> <li>Signposting with routes and distances is partially available</li> </ul>
		E–F	<ul style="list-style-type: none"> <li>Signposting with routes and distances is inadequate or missing</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>
Amenity	Aesthetics	A–B	<ul style="list-style-type: none"> <li>Clean and aesthetically pleasing (eg greenery, view, design, artwork)</li> </ul>
		C–D	<ul style="list-style-type: none"> <li>Clean</li> </ul>
		E–F	<ul style="list-style-type: none"> <li>Unclean (graffiti, garbage, etc)</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>
	Comfort and convenience features	A–C	<ul style="list-style-type: none"> <li>Good comfort and convenience features (bike parking, noise protection, change facilities, lockers, etc)</li> </ul>
		D–F	<ul style="list-style-type: none"> <li>Poor to fair comfort and convenience features (no parking, excessive noise, no change facilities, no lockers, etc)</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>N/A – The measure is not applicable to the site and the proposal being assessed</li> </ul>
	Security	A–C	<ul style="list-style-type: none"> <li>Good to high-level security (well-lit, no or limited history of criminality or disturbance, sufficient number of cyclists, etc)</li> </ul>
		D–F	<ul style="list-style-type: none"> <li>Poor to fair level security (not well-lit, with history of criminality or disturbance, low number of cyclists, etc)</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>
	Pavement ride quality	A–B	<ul style="list-style-type: none"> <li>Road surface is smooth and even</li> </ul>
		C–D	<ul style="list-style-type: none"> <li>Road surface is moderately smooth and even</li> </ul>

CLOS needs	CLOS measure	Rating	Service measure values
		E-F	<ul style="list-style-type: none"> <li>Road surface is not smooth and even</li> </ul>
		N/A	<ul style="list-style-type: none"> <li>N/A – the measure is not applicable to the site and the proposal being assessed</li> </ul>

**Table A.2 Danish cycling level of service on unprotected roadways**

Factor	Data used
Road length	Kilometres
Motor vehicles in both directions	One of: <ul style="list-style-type: none"> <li>AADT</li> <li>weekday 6 am–6 pm</li> <li>weekday peak hour.</li> </ul>
Motor vehicle speed	Average speed km/h
Land use on both road sides	<ul style="list-style-type: none"> <li>Residential, &gt;50% residence in ground floor</li> <li>Shopping, &gt;30% shops in ground floor</li> <li>Mixed, other roads in urban area</li> <li>Rural fields, mostly surrounding fields</li> <li>Rural forest, mostly surrounding forest.</li> </ul>
Average cross section (metres)	Sum of widths for: <ul style="list-style-type: none"> <li>Sidewalk (m)</li> <li>Buffer area between sidewalk and bicycle facility</li> <li>Bicycle track</li> <li>Bicycle lane/paved shoulder</li> <li>Buffer area between bicycle facility and drive lane</li> <li>Nearest drive lane.</li> </ul>
Median strip	Yes/No
Drive lanes	<ul style="list-style-type: none"> <li>1–3 drive lanes</li> <li>4 or more drive lanes</li> </ul>
Bus stop	Yes/No
Trees and bigger plantings	None/One or more per 50 m of road

Factor	Data used
Pedestrian traffic on nearest roadside	Weekday peak hour
Bicycle and moped traffic in both directions	One of: <ul style="list-style-type: none"> <li>• AADT</li> <li>• weekday 6 am–6 pm</li> <li>• weekday peak hour</li> </ul>
Parked cars per 100m	<ul style="list-style-type: none"> <li>• Total</li> <li>• Only nearest roadside</li> </ul>

Table A.3 Danish cycling level of service on roadway segments

Location	Factor	Categories
Urban roadways	Motor vehicles (AADT/vehicles per 40s)	<ul style="list-style-type: none"> <li>• &lt;3,500/0–2</li> <li>• 3,500–7,499/3–5.</li> <li>• 7,500–12,500/6–8.</li> <li>• &gt;12,500/9 or more</li> </ul>
	Average speed of motor vehicles (km/h)	<ul style="list-style-type: none"> <li>• &lt;45</li> <li>• 45–49</li> <li>• 50–55</li> <li>• &gt;55</li> </ul>
	Type of pedestrian facility	<ul style="list-style-type: none"> <li>• Sidewalk</li> <li>• No sidewalk</li> </ul>
	Type of bicycle facility	<ul style="list-style-type: none"> <li>• One-way bicycle track (curb or diving verge to drive lane)</li> <li>• Bicycle lane (inclusive 30 cm white line to drive lane)</li> <li>• Drive lane</li> </ul>
	Type of land use/building	<ul style="list-style-type: none"> <li>• Shopping (&gt;30% shops in ground floor)</li> <li>• Residential</li> <li>• Mixed use (&lt;30% shops and &lt;50% housing in ground floor)</li> </ul>
Rural roadways	Motor vehicles (AADT/vehicles per 40s)	<ul style="list-style-type: none"> <li>• &lt;3,500/0–2.</li> <li>• 3,500–9,500/3–6</li> </ul>



Appendix A: CLOS framework

Location	Factor	Categories
		<ul style="list-style-type: none"> <li>• &gt;9,500/7 or more</li> </ul>
	Average speed of motor vehicles (km/h)	<ul style="list-style-type: none"> <li>• &lt;75</li> <li>• 75-83</li> <li>• &gt;83</li> </ul>
	Type of pedestrian and bicycle facility	<ul style="list-style-type: none"> <li>• One- or two-way bicycle track (diving verge to drive lane)</li> <li>• Paved shoulder (inclusive 20 cm or wider white line to drive lane)</li> <li>• Drive lane</li> </ul>

**Table A.4 NCHRP bicycle segment LoS**

Peak hour factor
Total number of directional through lanes
Directional motorised vehicle volume (vph)
Effective speed factor
Average running speed of motorised vehicles (mph)
Proportion of heavy vehicles in motorized vehicle volume
FHWA's five-point pavement surface condition rating (5=excellent, 1=poor, 3=average/default)
Average effective width outside through lane (ft)
Percentage of segment with occupied on-street parking
Width of paving between the outside lane stripe and the edge of pavement (ft)
Effective width as a function of traffic volume (ft)
Width outside through lane plus paved shoulder (including bike lane where present) (ft)

**Table A.5 NCHRP bicycle intersection LoS**

Total width of outside through lane and bike lane (if present) on study direction of street (ft)
The curb-to-curb width of the cross-street at the intersection (ft)
Volume of directional traffic (vph)
Total number of through lanes on the subject approach to the intersection

Table A.6 Transport for London cycling level of service assessment

Factor	Indicator	Critical*	Basic CLOS (score=0)	Good CLOS (score=1)	Highest CLOS (score=2)
<b>Safety</b>					
Collision risk	Left/right hook at junctions.	Heavy streams of turning traffic cut across main cycling stream.	Side road junctions frequent and/or untreated. Conflicting movements at major junctions not separated.	Fewer side road junctions. Use of entry treatments. Conflicting movements on cycle routes are separated at major junctions.	Side roads closed or footway is continuous. All conflicting streams separated at major junctions.
	Collision alongside or from behind.	Nearside lane in range 3.2 m to 4.0 m.	Cyclists in wide (4 m+) nearside traffic lanes or cycle lanes less than 2 m wide.	Cyclists in dedicated cycle lanes at least 2 m wide.	Cyclists separated from motorised traffic.
	Kerbside activity or risk of collision with door.	Cycle lanes <1.5 m alongside parking/loading with no buffer.	Frequent kerbside activity/ effective with for cyclists of 1.5 m.	Less frequent kerbside activity/ effective width for cyclists of 2 m.	No kerbside activity/ no interaction with vehicles parking or loading.
	Other vehicle fails to give way or disobeys signals.		Poor visibility, no route continuity across junctions and unclear priority.	Clear route continuity through junctions, good visibility, priority clear for all users, visual priority for cyclists across side roads.	Cycle priority at signalised junctions; visual priority for cyclists across side roads.
Feeling of safety	Separation from heavy traffic.		Cyclists in general traffic lanes or cycle lanes less than 2 m.	Cycle lanes at least 2 m wide.	Cyclists physically separated from other traffic at junctions and on links, or no heavy freight.
	Speed of traffic (where cyclists are not separated).	85th percentile greater than 30 mph.	85th percentile greater than 25 mph.	85th percentile 20–25 mph.	85th percentile less than 20 mph.
	Total volume of traffic (where cyclists are not separated).	>1,000 vehicles/hour at peak.	500–1,000 vehicles/hour at peak (but becomes 'critical' if 5% or more are heavy goods vehicles (HGVs)).	200–500 vehicles/hour at peak (but becomes 'basic' if 2% or more are HGVs).	<200 vehicles/hour at peak.
	Interaction with HGVs.	Frequent, close interaction.	Frequent interaction.	Occasional interaction.	No interaction.

Appendix A: CLOS framework

Factor	Indicator	Critical*	Basic CLOS (score=0)	Good CLOS (score=1)	Highest CLOS (score=2)
Social safety	Risk/fear of crime.		High risk: 'ambush spots', loitering, poor maintenance.	Low risk: area is open, well designed and maintained.	No fear of crime: high quality street scene and pleasant interaction.
	Lighting.		Long stretches of darkness.	Short stretches of darkness.	Route lit thoroughly.
	Isolation.		Route passes far from other activity, for most of the day.	Route close to activity, for all of the day.	Route always overlooked.
	Impact of highway design on behaviour.		Layout encourages aggressive behaviour.	Layout controls behaviour throughout.	Layout encourages civilised behaviour: negotiation and forgiveness.
<b>Directness</b>					
Journey time	Ability to maintain own speed on links.		Cyclists travel at speed of slowest vehicle ahead (including other cyclists).	Cyclists can usually pass other vehicles (including cyclists).	Cyclists can always pass other vehicles.
	Delay to cyclists at junctions.		Journey time longer than motor vehicles.	Journey time around the same as motor vehicles.	Journey time less than motor vehicles.
Value of time (VoT)	For cyclists compared to private car use (normal weather conditions).		VoT greater than private car use value due to some site-specific factors.	VoT equivalent to private car use: similar delay-inducing factors and convenience.	VoT less than private car use value due to attractive nature of route.
Direct-ness	Deviation of route (against straight line or nearest main road alternative).		Deviation factor greater than 40%.	Deviation factor 20–40%.	Deviation factor less than 20%.
Connections	Ability to join / leave route safely and easily.		Cyclists cannot connect to other routes without dismounting.	Cyclists share connections with motor traffic.	Cyclists have dedicated connections to other routes.
	Density of other routes.		Network density mesh width >400m.	Network density mesh width 250–400 m.	Network density mesh width <250 m.
Way-finding	Signing.		Basic direction signing (cyclists follow road signs and markings).	Some cycle-specific direction signing.	Consistent signing of range of routes and destinations at decision points.
<b>Comfort</b>					

Factor	Indicator	Critical*	Basic CLOS (score=0)	Good CLOS (score=1)	Highest CLOS (score=2)
Surface quality	Defects: non-cycle friendly ironworks, raised/sunken covers/ gullies.	Major defects.	Many minor defects.	Few minor defects.	Smooth, high-grip surface.
Surface material	Construction.		Hand-laid asphalt or unstable blocks/sets.	Machine laid asphalt concrete or HRA; smooth blocks.	Machine laid asphalt concrete; smooth and firm blocks undisturbed by turning vehicles.
Effective width without conflict	Clear nearside space in secondary position or motor vehicle speed/ volume in primary position.	Secondary: <1.5 m. Primary: high motor vehicle flow.	Secondary: 1.5 m. Primary: medium motor vehicle flow.	Secondary: 1.5–2.0 m. Primary: low motor vehicle flow.	Secondary: >2.0 m. Primary: no overtaking by motor vehicles.
Gradient	Uphill gradient over 100 m.		>5%.	3–5%.	<3%.
Deflections	Pinch points caused by horizontal deflections.		(Remaining) lane width <3.2 m.	(Remaining) lane width >4.0 m or <3.0 m (low motor vehicle flow).	Traffic is calmed so no need for horizontal deflections.
Undulations	Vertical deflections.		Round top humps.	Sinusoidal humps.	No vertical deflections.
<b>Attractiveness</b>					
Impact on walking	Pedestrian comfort level (PCL).		Reduction in PCL to C, D or E.	No impact on pedestrian provision or PCL never lower than B.	Pedestrian provision enhanced by cycling provision or PCL A.
Greening	Green infrastructure or sustainable materials incorporated into design.		No greening element.	Some greening elements.	Full integration of greening elements.
Air quality	PM10 and NOX values referenced from concentration maps.		Medium to high.	Low to medium.	Low.

Appendix A: CLOS framework

Factor	Indicator	Critical*	Basic CLOS (score=0)	Good CLOS (score=1)	Highest CLOS (score=2)
Noise pollution	Noise level from recommended riding range.		>78DB.	65–78DB.	<65DB.
Minimise street clutter	Signing required to support scheme layout.		Large amounts of regulatory signing to conform with complex layout.	Moderate amount of signing, particularly around junctions.	Minimal signing, eg for wayfinding purposes only.
Secure cycle parking	Ease of access to secure cycle parking on- and off-street.		No additional secure cycle parking.	Minimum levels of cycle parking provided (ie to London Plan standards).	Cycle parking is provided to meet future demand and is of good quality and securely located.
<b>Adaptability</b>					
Public transport integration	Smooth transition between modes or route continuity maintained through interchanges.		No consideration for cyclists within interchange.	Cycle route continuity maintained through interchange and some cycle parking available.	Cycle route continuity maintained and secure cycle parking provided. Transport of cycles available.
Flexibility	Facility can be expanded or layouts adopted within area constraints.		No adjustments are possible within constraints. Road works may require some closure.	Links can be adjusted to meet demand but junctions are constrained by vehicle capacity limitations. Road works will not require closure; cycling will be maintained although route quality may be compromised to some extent.	Layout can be fully adapted freely without constraint to meet demand or collision risk. Adjustments can be made to maintain full route quality when roadworks are present.
Growth enabled	Route matches predicted usage and has exceedance built into the design.		Provision does not match current levels of demand.	Provision is matched to predicted demand flows.	Provision has spare capacity for large increases in predicted cycle use.

Table A.7 Bicycle Victoria cycling level of service assessment tool (CLOSAT)

Class	Subset	Facility	Value
Off road	Midblock Left side One direction	2.0 m	6
		2.5 m	9
		3.0 m	12
		3.5 m	13
		4.0 m	14
		Central line marking	1
		Lighting	2
		<0.5 m clearance to traffic lane	-4
		<0.5 m lateral clearance to obstruction	-1
		0.0 m offset of object from path	-2
		No edge delineation – substrate differential	-1
		Circuitous path, radius <25 m, length >+20 m	-2
		Chicane, radius <3 m	-3
		Central bollard	-2
		Entryways across path <3 m sight setback	-4
		Entryways across path >3 m sight setback	-2
		Gradient >7% for 100 m	-2
		Gradient >10% for 100 m	-4
		Surface – gravel or timber decking	-6
		Uneven surface	-3
	Intersection Left side One direction	Grade separated	14
		Signalised POS with bike lanterns	12
		Bicycle priority, raised (100 mm)	6
		Bicycle priority, not raised	3
		Zebra/POS crossing (dismount)	2
		Give way & median island or kerb outstand	2
		Lighting	2
		Smooth pram ramps (invert <1 in 8)	1
		Circuitous path, radius <3 m	-1
		Heavy turn volume, no signed slip crossing	-2
		Crossing delay (secs): <25, <50, 50+	0,-2,-3
On-road bike lanes	Midblock One direction	Nothing	0
		Wide kerbside lane	1
		1.0 m paint	3
		1.2 m paint	5
		1.5 m paint	8
		1.8 m paint	9
		2.0 m paint	10

Class	Subset	Facility	Value
		Separated by profiled line	3
		Separated by parking	4
		Bus lane = <10, <20, 20+ buses/hour	11,6,2
		Speed: 50 km/h, 40 km/h, 30 km/h	1,3,4
		Speed: 70 km/h, 80 km/h, 90+km/h	-3,-10,-15
		Side streets without green	-2
		Parking, no 0.5 m chevron or reversing zone	-3
		<0.5m la clearance to obstruction	-2
		Uneven surface	-3
	Intersection One direction	2 lane roundabout approach (no other + score)	0
		Intersection approach lane straight	4
		Intersection approach lane deviated to kerb	2
		Lane through intersection	3
		Intersection departure lane	2
		Storage box	1
		Early start	3
		Green on approach	3
		Speed: 50 km/h, 40 km/h, 30 km/h	1,3,4
		Speed: 70 km/h, 80 km/h, 90+ km/h	-3,-10,-15
		Heavy left turn volume	-3
		Crossing delay (secs): <25, <50, 50+	0,-2,-3
		Mixed traffic	Midblock
Bike boulevard and marked lanes	12		
Intersection	As for separated paths		
	On bike boulevards only		

Table A.8 Queensland LoS model for bicycle riders

Link type	On road (no facility)
	On road (bicycle lane)
	On road (protected lane)
	Off road (shared path)
On-street parking	No parking
	Kerbside
Posted speed limit	50 km/h
	60 km/h
	80 km/h
Rider type	Cautious
	Confident

	All types
<b>Car volume</b>	Vehicles per hour (n)
<b>Bus volume</b>	Vehicles per hour (n)
<b>Overtake pedestrian</b>	Every X minutes
<b>Meet oncoming user</b>	Every X minutes
<b>Incur delay</b>	Every X minutes
<b>Travel time</b>	Minutes



# Appendix B: Route maps

Figure B.1 Christchurch route 1



Figure B.2 Christchurch route 2

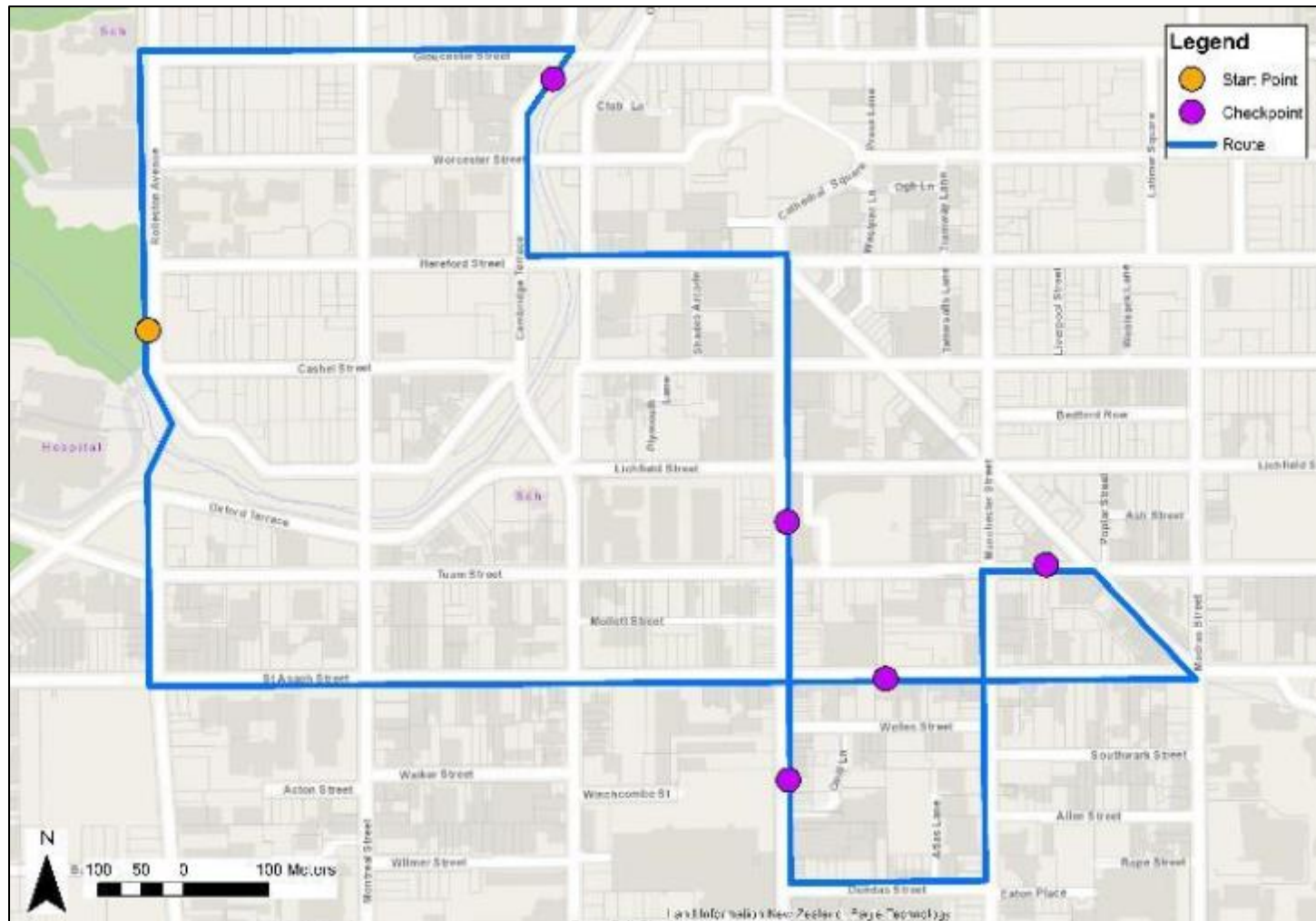


Figure B.3 Wellington route 1

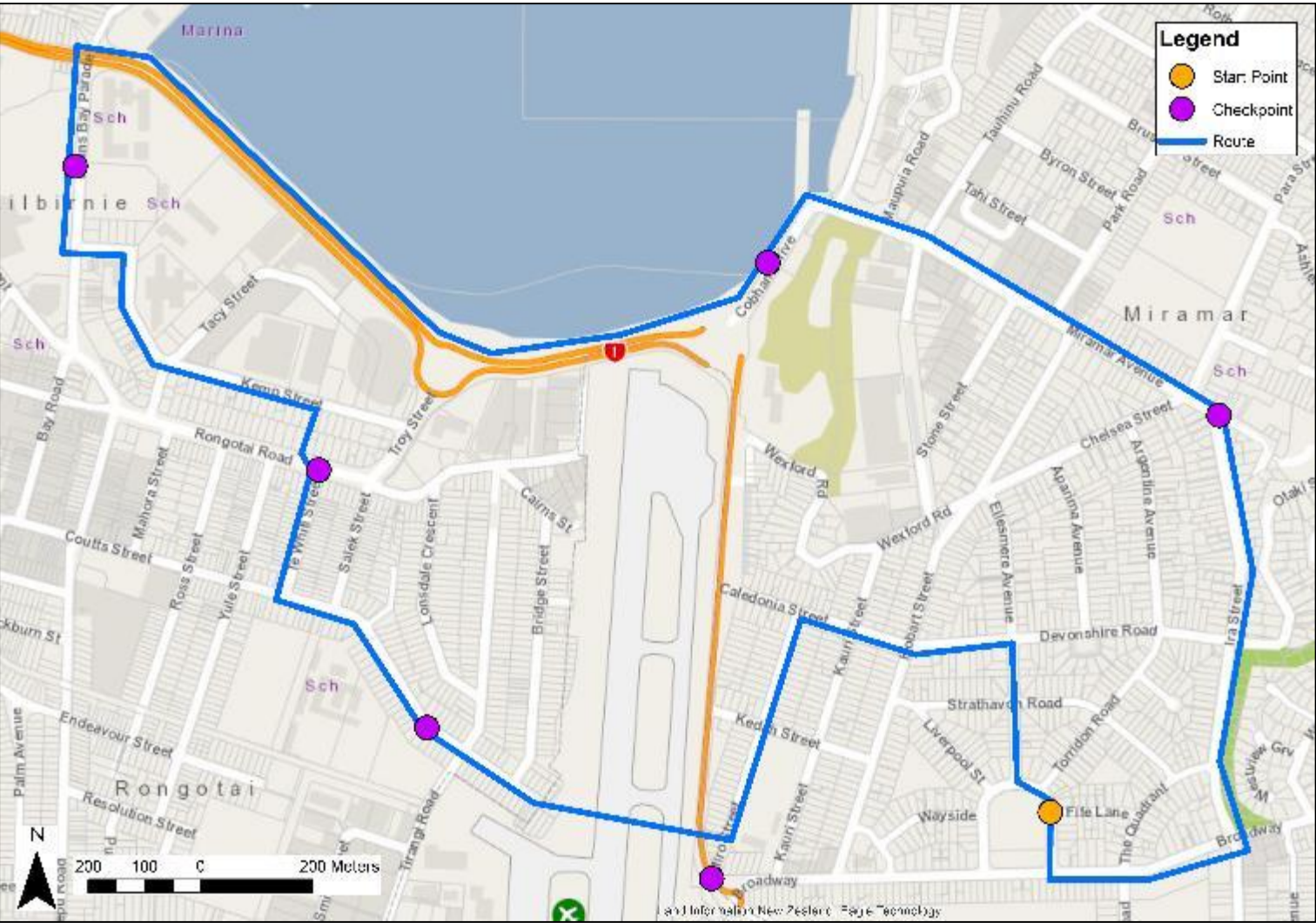




Figure B.4 Wellington route 2

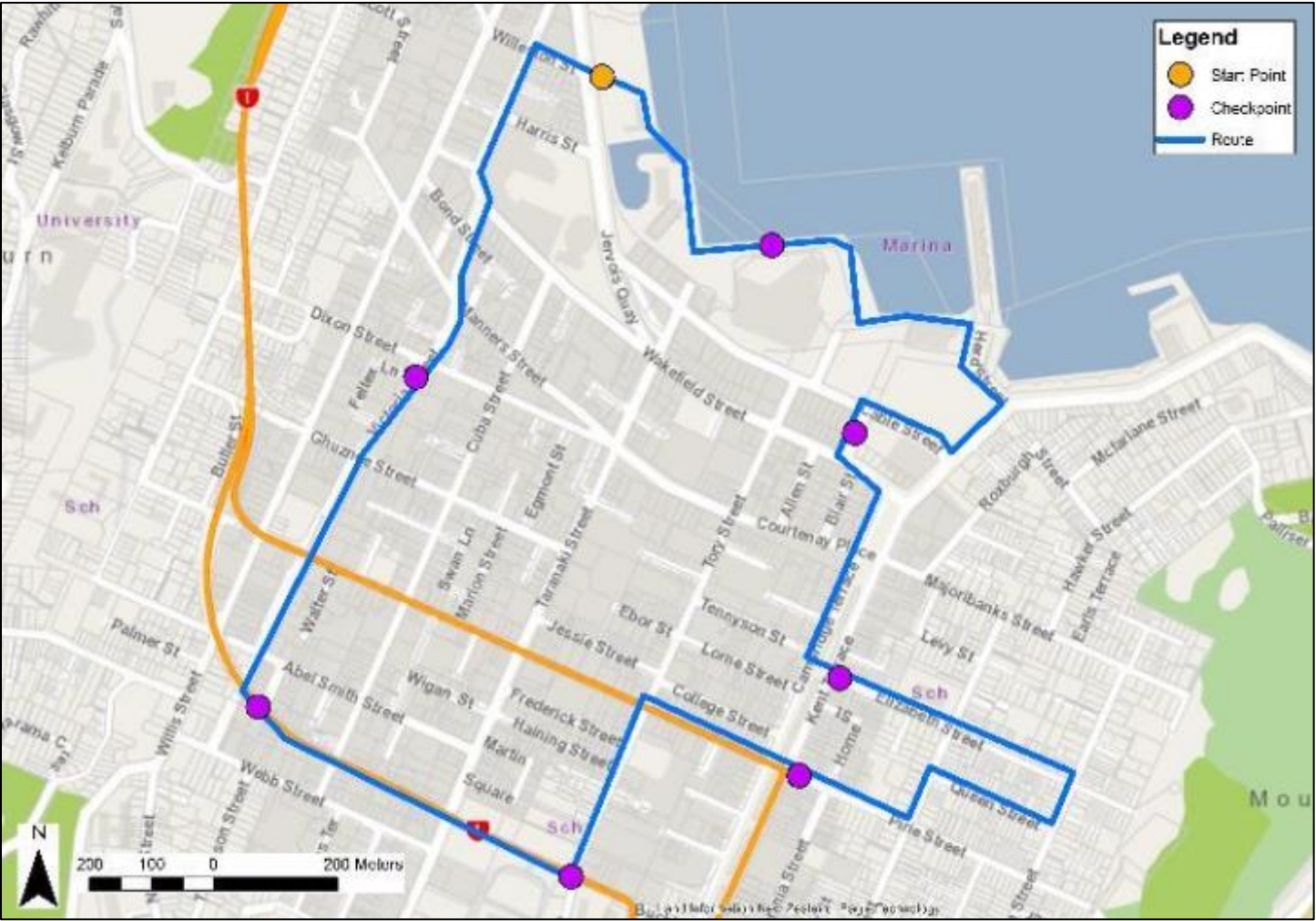


Figure B.5 Auckland route 1

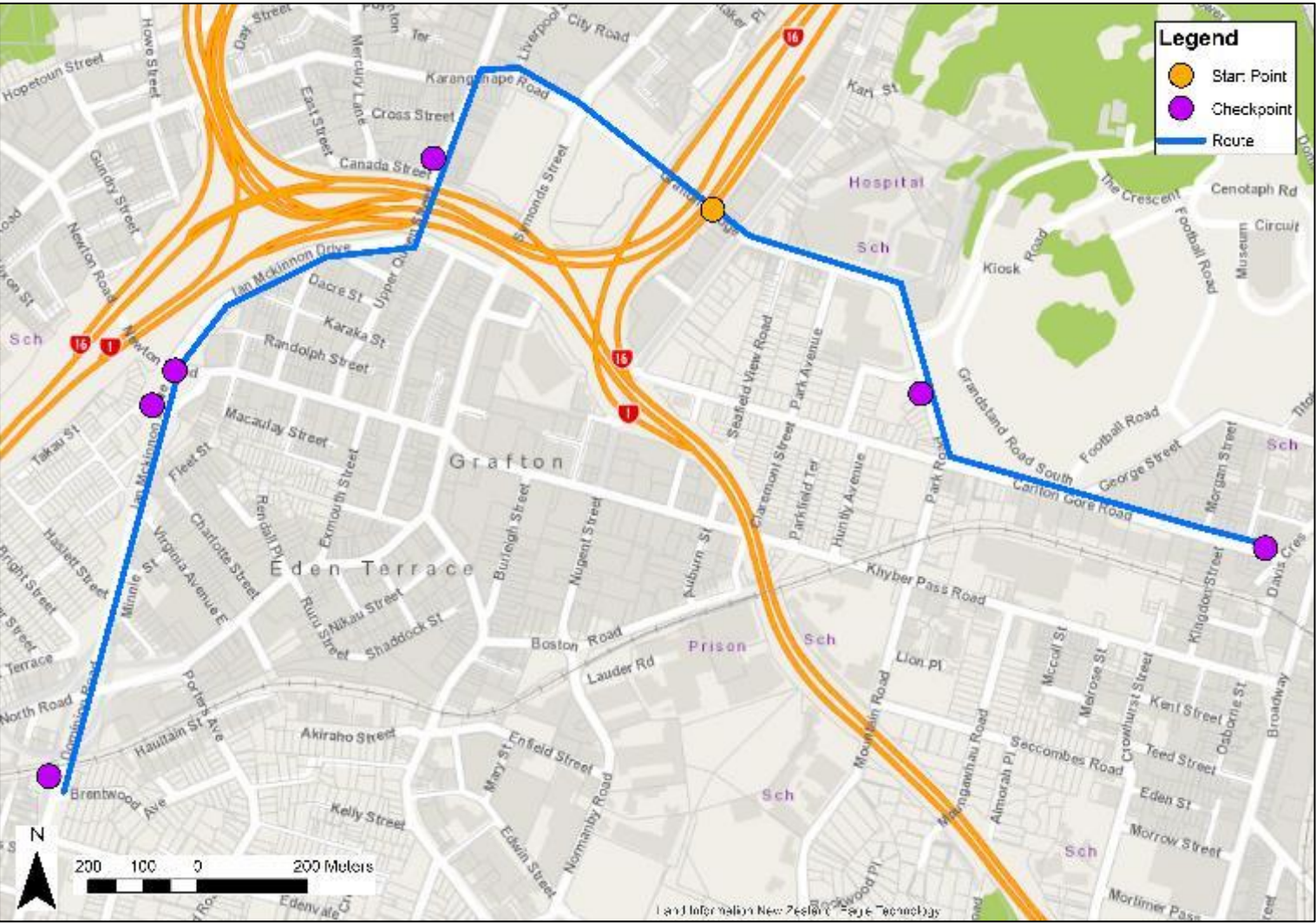
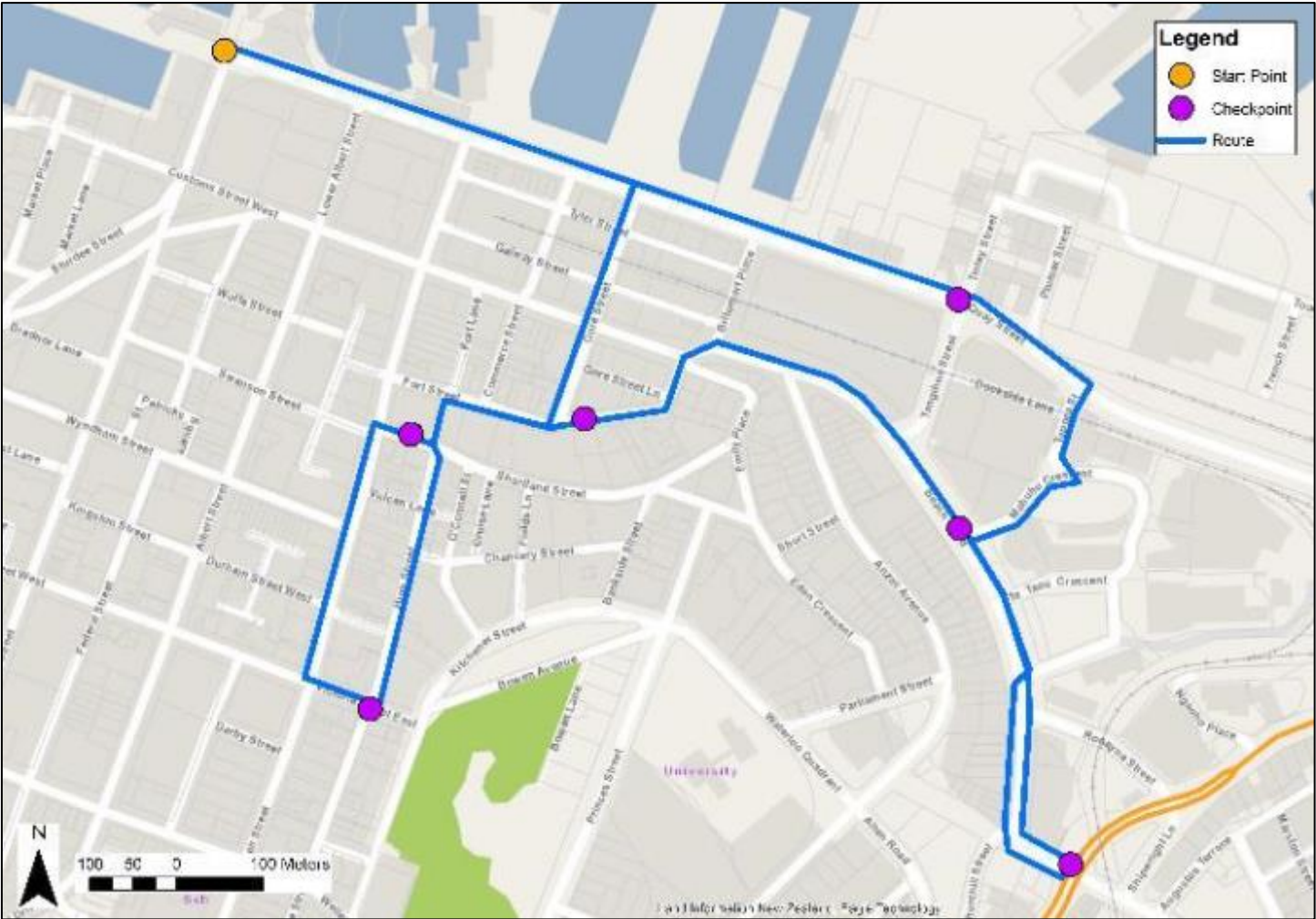




Figure B.6 Auckland route 2



## Appendix C: Video clip summary

ID	Segment description	Type	Overtaking traffic	Oncoming traffic	Intersection traffic	Parked vehicles	Pedestrians	Cyclists
1	Te Whiti Street	Painted cycle lane	no	no		yes		no
2	Cobham Drive	Sealed shoulder - no parking	yes					yes
3	Miramar Ave roundabouts	Roundabout	no	yes	yes	no	no	no
4	Airport underpass	Shared path					yes	yes
5	Kemp Street	Shared path				yes	no	no
6	Evans Bay Parade - Cobham Drive X intersection	Signalised intersection		yes	yes		no	no
7	Cobham Drive shared path first segment	Shared path	yes				no	no
8	Cobham Drive shared path second segment	Shared path	yes				no	no
9	Miramar Ave roundabouts	Roundabout	no	no	no			
10	Ira Street	Sealed shoulder - with parking	yes	yes		yes	no	no
11	Ira Street - Broadway roundabout	Roundabout	no	yes	yes	yes	no	no
12	Coutts Road - Tirangi Road roundabout	Roundabout		yes	yes		no	no
13	Kemp Street	Shared path				yes	no	no
14	Coutts Road - Tirangi Road roundabout	Roundabout		no	yes			no
15	Cobham Drive	Sealed shoulder - no parking	yes				no	no
16	Victoria Street - Dixon Street X intersection	Signalised intersection	yes		yes	yes		no
17	Victoria Street - Vivian Street X intersection	Signalised intersection	yes		yes		no	no

ID	Segment description	Type	Overtaking traffic	Oncoming traffic	Intersection traffic	Parked vehicles	Pedestrians	Cyclists
18	Oriental parade angled parking	Sealed shoulder - with parking	yes	yes		yes	no	no
19	Wellington Waterfront Te Papa section	Shared path					yes	yes
20	Wellington Waterfront Frank Kitts Lagoon bridge	Shared path					yes	yes
21	Vivian Street	Mixed traffic	yes			yes	yes	no
22	Aro Drive - Cuba Street X intersection	Signalised cycle crossing			yes		yes	no
23	Vivian Street	Mixed traffic	yes			yes	no	no
24	Queen Street	Neighbourhood greenway	no			yes	no	no
25	Victoria Street sharrows	Mixed traffic - sharrows	yes		yes		no	no
26	Victoria Street - Vivian Street X intersection	Signalised intersection	yes		yes		no	no
27	Elizabeth Street	Neighbourhood greenway	no			yes	no	no
28	Tory Street	Mixed traffic	no	yes		yes	no	no
29	Upper Queen Street and Ian McKinnon Drive intersection (southbound)	Signalised cycle crossing			yes		no	no
30	North Western Cycleway (uphill to Ian McKinnon Drive)	Shared path					yes	yes
31	Carlton Gore Road separated cycle lane (downhill)	Separated cycle lane	yes	yes				no
32	Carlton Gore Road separated cycle lane (uphill midsection)	Separated cycle lane	yes	yes		yes	yes	no
33	North Western Cycleway (downhill to Piwakawaka Street)	Shared path					yes	yes
34	Carlton Gore Road painted cycle lane (downhill)	Painted cycle lane	no	yes		yes	no	no



Appendix C: Video clip summary

ID	Segment description	Type	Overtaking traffic	Oncoming traffic	Intersection traffic	Parked vehicles	Pedestrians	Cyclists
35	Park Road bus lane	Bus lane	yes	yes	yes			no
36	Carlton Gore Road painted cycle lane (uphill)	Painted cycle lane	yes	yes		yes		no
37	North Western Cycleway (downhill to Piwakawaka Street)	Shared path					no	yes
38	Dominion Road on-ramp crossing (northbound)	Painted cycle lane - side road	yes		yes		yes	no
39	Dominion Road off-ramp crossing (southbound)	Painted cycle lane - side road	yes		no			no
40	Carlton Gore Road painted cycle lane (downhill)	Painted cycle lane	no	yes		yes		no
41	Carlton Gore Road separated cycle lane (uphill top section)	Separated cycle lane	yes			yes		no
42	Dominion Road on-ramp crossing (southbound)	Painted cycle lane - side road	yes		yes	yes		no
43	Dominion Road shared path (bridge)	Shared path	yes				yes	no
44	Beach Road separated cycle lane (northbound)	Cycle path		yes			yes	yes
45	Beach Road separated cycle lane (northbound)	Cycle path					yes	yes
46	Quay Street separated cycle lane (westbound)	Separated cycle lane		yes			no	yes
47	Quay Street separated cycle lane (eastbound)	Separated cycle lane	yes				no	yes
48	Beach Road separated cycle lane (southbound)	Separated cycle lane	no					yes
49	Quay Street separated cycle lane (westbound)	Separated cycle lane		yes			yes	no

Factors affecting cycling levels of service

ID	Segment description	Type	Overtaking traffic	Oncoming traffic	Intersection traffic	Parked vehicles	Pedestrians	Cyclists
50	Quay Street separated cycle lane (eastbound)	Separated cycle lane	yes					no
51	Quay Street separated cycle lane and Port entrance (eastbound)	Painted cycle lane - side road			yes			no
52	Queen Street and Shortland Street intersection	Signalised intersection	no	yes	yes			no
53	Papanui Road at Merivale Shopping Centre	Mixed traffic	yes	yes		yes	no	no
54	Rutland Street separated cycle lane (one-way, south end)	Separated cycle lane	yes	yes		yes		yes
55	Leinster Road and Rossall Street intersection	Non-signalised intersection			yes		no	no
56	Railway shared pathway	Shared path					yes	yes
57	Idris Road cycle lane	Painted cycle lane	no	yes		yes		no
58	Blighs Road cycle lane	Painted cycle lane	yes	yes		yes		no
59	Rutland Street and Innes Road intersection	Cycle signalised intersection	yes		yes			no
60	Idris Road cycle lane	Painted cycle lane	yes	yes		yes		no
61	Papanui Road cycle lane	Painted cycle lane	yes	yes		yes		no
62	Rutland Street separated cycle lane (two-way, north end)	Separated cycle lane	no	no		no		no
63	Papanui Road at Merivale Shopping Centre	Mixed traffic	yes	yes		yes		no
64	Railway shared pathway	Shared path					no	yes
65	Papanui Road at Merivale Shopping Centre	Mixed traffic	yes	no		yes		no
66	Rutland Street separated cycle lane (one-way, north end)	Separated cycle lane	no	no	yes			no

Appendix C: Video clip summary

ID	Segment description	Type	Overtaking traffic	Oncoming traffic	Intersection traffic	Parked vehicles	Pedestrians	Cyclists
67	Rolleston Ave shared pathway (north segment)	Shared path					yes	no
68	Colombo Street cycle lane (Lichfield - Tuam)	Separated cycle lane	no	no				no
69	Colombo Street and Tuam Street intersection	Cycle signalised intersection	yes	yes	yes			no
70	Manchester Street cycle lane (St Asaph - Tuam)	Painted cycle lane	yes	no	yes	yes		no
71	Avon River Bridge shared pathway	Shared path					yes	no
72	Gloucester Street and Cambridge Terrace intersection	Signalised intersection			yes			no
73	Manchester Street cycle lane (Dundas - St Asaph)	Painted cycle lane	yes	yes		yes		no
74	Colombo Street cycle lane (Tuam - St Asaph)	Separated cycle lane	yes				yes	no
75	St Asaph Street and Antigua Street intersection	Signalised intersection	yes		yes			no
76	Avon River Bridge shared pathway	Shared path					yes	no
77	Manchester Street cycle lane (St Asaph - Tuam)	Painted cycle lane	yes	yes	yes	yes		no

## Appendix D: CLOS real-time and video survey ratings

The table below presents mean ratings by individual midblock segments from the real-time and video surveys. Note that not all segments were rated in the video survey so there are gaps in this data.

Segment type	Segment name	Mean real-time rating	Mean video survey rating	Willingness to ride (video survey)
Shared pathway	Avon River Bridge (Christchurch)	4.6	4.6	94%
	Railway shared pathway (Christchurch)	5.4	5.2	98%
	Rolleston Ave (Christchurch)	4.2	4.1	83%
	Airport underpass (Wellington)	5.2	4.6	93%
	Cobham Drive (Wellington)	5.3	4.8	94%
	Aro Drive (SH1) (Wellington)	5.2	Not rated	Not rated
	Kemp Street (Wellington)	3.0	3.8	69%
	Wellington Waterfront – Chaffers Bridge	5.0	Not rated	Not rated
	Wellington Waterfront – Frank Kitts Lagoon Bridge	4.5	4.8	93%
	Wellington Waterfront – Marina section	5.2	Not rated	Not rated
	Wellington Waterfront – Te Papa section	5.5	5.2	97%
	Dominion Road (Auckland)	4.5	4.2	93%
	Northwestern Cycleway downhill (Auckland)	3.7	4.8	96%
	Northwestern Cycleway uphill (Auckland)	3.6	5.2	99%
	Upper Queen Street (Auckland)	5.2	Not rated	Not rated
Separated cycle lane	Colombo Street – Lichfield to Tuam (Christchurch)	5.0	5.0	98%
	Colombo Street – Tuam to St Asaph (Christchurch)	5.3	5.1	99%
	Rutland Street – one-way north end (Christchurch)	5.4	5.1	95%
	Rutland Street – one-way south end (Christchurch)	5.3	5.2	99%
	Rutland Street – two-way north end (Christchurch)	5.2	5.5	98%

Appendix D: CLOS real-time and video survey ratings

Segment type	Segment name	Mean real-time rating	Mean video survey rating	Willingness to ride (video survey)
	St Asaph Street (Christchurch)	5.4	Not rated	Not rated
	Victoria Street (Wellington)	4.6	Not rated	Not rated
	Beach Road northbound (Auckland)	4.9	5.3	95%
	Beach Road southbound (Auckland)	5.2	5.7	99%
	Carlton Gore Road downhill (Auckland)	4.9	5.5	99%
	Carlton Gore Road uphill (Auckland)	4.9	5.1	94%
	Carlton Gore Road uphill (Auckland)	5.4	5.0	95%
	Quay Street eastbound (Auckland)	5.0	5.4	98%
	Quay Street westbound (Auckland)	5.6	5.1	96%
<b>Painted cycle lane or sealed shoulder</b>	Blighs Road (Christchurch)	4.5	3.5	86%
	Idris Road (Christchurch)	4.8	4.3	97%
	Papanui Road (Christchurch)	4.5	4.5	97%
	Manchester Street – Dundas to St Asaph (Christchurch)	3.3	3.0	74%
	Manchester Street – St Asaph to Tuam (Christchurch)	4.7	3.8	89%
	Cobham Drive (Wellington)	3.3	3.8	81%
	Coutts Road (Wellington)	4.0	Not rated	Not rated
	Devonshire Road (Wellington)	4.1	Not rated	Not rated
	Te Whiti Street (Wellington)	5.1	3.7	92%
	Victoria Street (Wellington)	4.1	Not rated	Not rated
	Carlton Gore Road downhill (Auckland)	4.3	4.5	97%
	Carlton Gore Road uphill (Auckland)	3.8	3.7	92%
<b>Bus lane</b>	Papanui Road (Christchurch)	4.4	Not rated	Not rated
	Cambridge Terrace (Wellington)	3.7	Not rated	Not rated
	Park Road (Auckland)	4.3	4.1	87%
	Queen Street (Auckland)	4.6	Not rated	Not rated

Segment type	Segment name	Mean real-time rating	Mean video survey rating	Willingness to ride (video survey)
<b>Neighbourhood greenway</b>	Elizabeth Street (Wellington)	4.5	4.1	93%
	Queen Street (Wellington)	4.9	4.8	99%
<b>Shared space</b>	Fort Street (Auckland)	5.0	Not rated	Not rated
<b>Mixed traffic</b>	Papanui Road at Merivale shopping centre (Christchurch)	3.5	3.6	88%
	Miramar Ave (Wellington)	3.7	Not rated	Not rated
	Miro Road (Wellington)	4.7	Not rated	Not rated
	Pirie Street (Wellington)	3.5	Not rated	Not rated
	Tory Street (Wellington)	4.2	4.0	87%
	Victoria Street - sharrows (Wellington)	4.2	3.5	87%
	Vivian Street (Wellington)	3.2	3.4	80%
	High Street (Auckland)	3.4	Not rated	Not rated