Requirements for Effective Cycling Infrastructure.

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ABSTRACT

Cycling infrastructure is physical structures and facilities used for the comfort and safety of cyclists. Examples include shared pathways, cycle lanes and neighbourhood greenways. This paper focuses on neighbourhood greenways and shared pathways. A neighbourhood greenway is the term used for a street that has been optimised for cycling and a shared pathway is a path for both cyclists and pedestrians. This study uses the Uni-Cycle route in Christchurch as a case study.

In the Uni-Cycle route, Hinau Street has been proposed as a neighbourhood greenway. Hinau Street's suitability as a neighbourhood greenway was assessed using speed, volume and positional data. The speed and volume data was collected using MetroCount road tubes. Positional data was recorded using 'Psion Organisers' on physical surveys. The street was found to be a low volume (<3000 veh/day), and low speed (<40k m/h) street as desired. The positional data found that cars moved over 20-30 cm when in the presence of a cyclist. It also identified that cars provided 1.6 m of separation on average when parking was present, compared to 1.7 m when there was no parking. Both separation results are above the 1.5 m recommended by the New Zealand Transport Agency.

The shared paths studied were Ilam Fields and Riccarton Bush. Manual surveys were conducted to determine volumes and modal split of path users. The surveys also utilised data from a previous study to establish a basic relationship between path width and user interactions. The survey data was also input into two existing industry tools; both found that the paths were of insufficient width.

A perception survey was undertaken to supplement the physical surveys and establish how the general public viewed the facilities. The survey identified that wider paths with markings were preferred for shared pathways and removing parking improved people's perceived comfort when using a neighbourhood greenway.

1. INTRODUCTION

1.1. Context

Christchurch City Council (CCC) is investing in a number of key cycle routes around the city. This has raised the question of what is required for effective cycling infrastructure.

Infrastructure is defined as the basic physical and organisational structures and facilities needed for the operation of a society. In this report cycling infrastructure will be referred to as the physical structures and facilities used for both comfort as safety along a cycling route. Examples of cycling infrastructure are shared pathways, cycle lanes, separated cycle paths and neighbourhood greenways. Supporting infrastructure such as bike parking can also be considered cycling infrastructure although, for the purpose of this study, these will not be considered.

This study focuses on neighbourhood greenways and shared pathways. The purpose of the study is to:

- Determine the road users' perception of shared pathways
- Identify a preference amongst pathway users with respect to road markings and signage
- Determine current usage of shared pathways in the proposed route
- Determine the volume and speed of vehicles currently using the local streets slated to become neighbourhood greenways
- Establish the current perception of the suitability of proposed greenway routes
- Find out road users' perception for what infrastructure is required to make the greenway work (including checking whether the existing traffic calming infrastructure is sufficient)

Figure 1. Shared Path at Riccarton Bush

Figure 2. Shared Path at Ilam Fields

1.2. Shared Pathways

Overview

Shared pathways, as shown in Figures 1 and 2, are off-road paths for cyclists and pedestrians. They can be either adjacent to a road or independent of the road network (Lieswyn, et al., 2012).

A large factor in the design of shared pathways is the width required to accommodate varying volumes. This is particularly important due to the inherent risks of mixing modes with significant speed differential. This study investigates the relationship between interactions and width for shared pathways in New Zealand.

Currently there are very few guidelines on the best practice design of shared pathways (Fowler, Lloyd & Munro, 2010). Two industry tools are available for determining the required path width. These tools were used evaluate the case study paths.

Shared Use Path Level of Service calculator

Commissioned by the United States Federal Highways Administration (FHWA), the Shared Use Path Level of Service Calculator was developed from new theoretical traffic-flow concepts, operational data and perception survey results of path users. It was adapted from Hein Botma's equations which were developed for use in the Netherlands (Federal Highways Administration, 2006). The equations however, did not take into account passive passing or delayed passings as cited in Federal Highways Administration (2006). Passive and delayed passings occur when the path width is insufficient or the path is blocked by a user travelling in the opposite direction. The FHWA adapted the equations to account for large variety in the speeds within a mode. For example there is a significant difference in the speed of a pedestrian who is walking compared with running, and a child cyclist compared to an adult cyclist (Federal Highways Administration, 2006).

The level of service is based on an estimated number of meetings and passings for a cyclist travelling along the path. The level of service calculator requires path width, the total volume of path users and the modal split of users. The calculator is limited to a path width between 2.44 m and 6.1 m (8-20 ft). It also assumes that the capacity of a two-way, one-lane path is 850 to 1,000 bicycles per hour (Federal Highways Administration, 2006).

Shared Path Width Model

ViaStrada were commissioned by VicRoads, the roading authority in Victoria, Australia to develop a model for determining the path width of shared pathways. Their model was created by adjusting the FHWA calculator to make it more suitable for Australian paths (including adjustments for tidal flow) (Fowler et al., 2010). Their model is presented as a graph. The graph uses the peak volumes of pedestrians and cyclists to recommend an appropriate shared path width or creation of separate facilities for each of the modes.

Our Model

Our model will take into account the 'interactions' encountered by users on our paths. This will produce a model to estimate the number of interactions per user for a given width of path. It is hoped that this will allow recommendations to be made as to how wide a path is required.

1.3. Neighbourhood Greenways

A neighbourhood greenway is also known as a bicycle boulevard. In the context of this project we will use the definition provided by Walker et al. (2009) which states a bicycle boulevard is "a low volume and low speed street that has been optimized for bicycle travel".

Neighbourhood greenways often utilise treatments such as traffic calming and reduction, signage, pavement markings, and intersection cross treatments in order to optimise the street for cyclists. Neighbourhood greenways generally try to link together key locations that cyclists would want to travel between, therefore they are often implemented as a network that runs parallel to major arterial routes (Walker, et al., 2009).

2. METHODOLOGY

2.1. Overview

The Uni-Cycle route (Figure 3) was selected as the case study for this report. The Uni-Cycle route links Canterbury University to the Christchurch central business district. It is the first route that will be implemented by the CCC as a part of their strategic transport plan for cycling. The Uni-Cycle route is made up of neighbourhood greenways, shared paths and separated cycle paths. This study focuses on the neighbourhood greenway at Hinau Street and shared paths at Ilam Fields and Riccarton Bush.

The proposal to use Hinau Street as a neighbourhood greenway raises the question of how suitable the street is in its current state. This report will evaluate the current conditions in Hinau Street. In the event that the street is deemed unsuitable, the report will attempt to identify the required infrastructure, such as signs and road markings, for creating a street that lends itself to use as a shared space.

The widths and perception of the paths will be examined to try and determine whether the current path width is suitable or whether the path width should be widened. If the path is of insufficient width, then a recommendation will be made on the extent of the width extension.

The shared path will also be investigated from a user's perception. Potential users will also be asked about treatments such as path markings.

2.2. Shared Paths

The study focussed on the Ilam Fields and Riccarton Bush shared pathways that travel through parks. Manual surveys were conducted at these sites. The surveys were over one hour periods at three different times: morning peak (8:00am – 9:00am), afternoon peak (4:30pm – 5:30pm) and middle of the day (11:00pm – 2:00pm). The surveys recorded user volumes by type (walker, jogger, slow cyclist and cyclist) as well as interactions between users (change in speed, deviation in path and collisions).

An additional survey was conducted at Riccarton Bush on Saturday 15th July in order to investigate the impact of markets, which are held in the space every Saturday and Sunday morning.

To ensure the largest sample size possible, the data we collected was combined with an existing University of Canterbury data set. This data set contained records of interactions and volumes on a number of other shared pathways around Christchurch. This data was collected by a single person, and the subjective nature of what

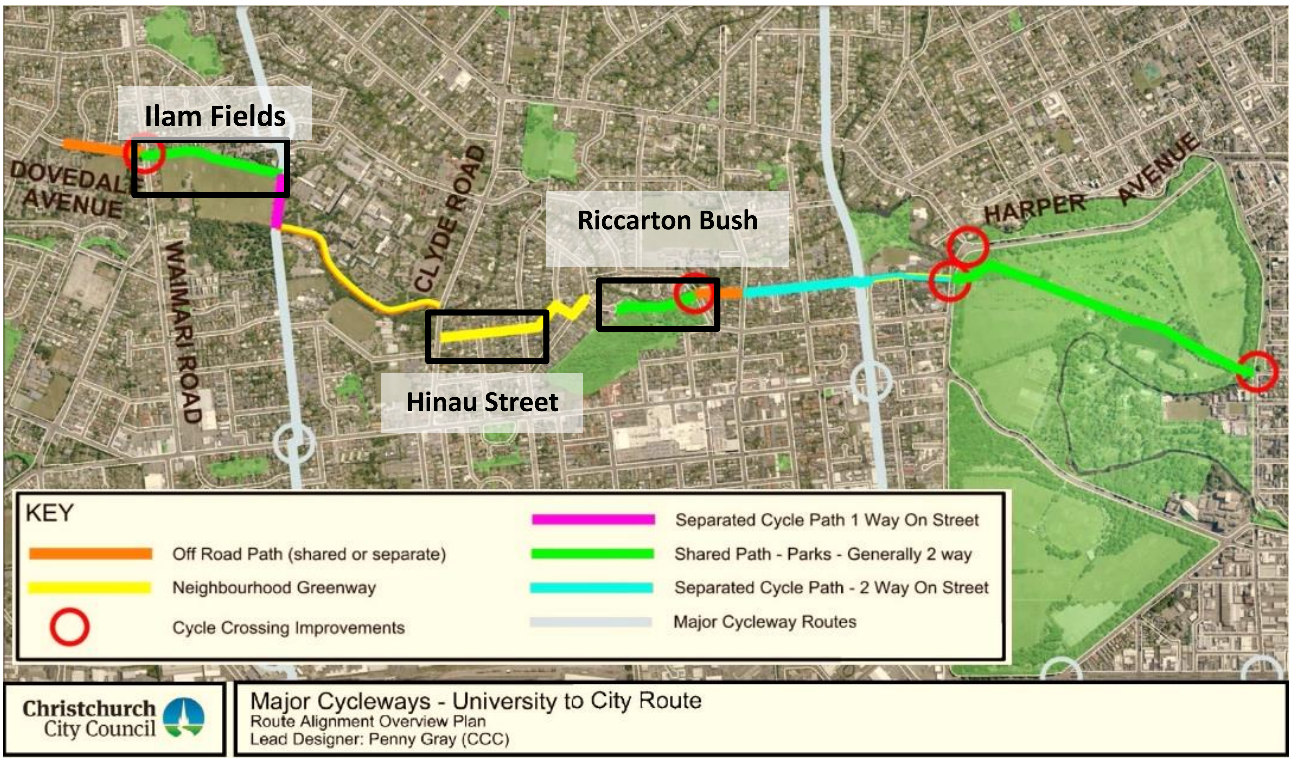

Figure 3. Uni-Cycle Route

Figure 4. Road tubes configuration on Hinau Street

Figure 5. Marks for Position Survey at Hinau Street

constitutes an 'interaction' meant that data needed to be normalised before it was analysed. This was done by using two paths of similar widths and volumes and comparing the recorded data. Theoretically, the data should produce the same number of interactions. If not then one data set could be scaled to ensure compatibility.

2.3. Neighbourhood Greenways

Speed and Volume

Speed and volume data was recorded on Hinau Street over a two week period. The data was collected using MetroCount equipment, with the MetroCount tubes set up between Clyde Road and Konini Street. The tubes used were thin walled rubber tubes in order to ensure that cyclists would be recorded. When starting the survey it was unknown how far the tubes were able to be stretched across the road before they were unable to transmit the signal from a bike. The configuration shown in (Figure 4) was used to mitigate uncertainty. Two MetroCount units were needed for this configuration and the data was combined later with duplicate entries removed. The MetroCount data was analysed using a combination of Microsoft Excel and MathWorks MATLAB to find representative volume and speed metrics. In this analysis the speeds of traffic were assumed to be normally distributed. This was supported by the shape of the data when plotted as a histogram.

Position

There are a number of survey methods for measuring the lateral interaction between vehicles and cyclists. One method utilised by the FHWA (2010) was to measure the distance between cyclists and a point of interest. For example this could be between a cyclist and a parked car (tyre to tyre), the kerb (tyre to kerb) or a passing car (tyre to tyre). The distance between cars and the stationary point of reference (kerb/parked car) used as reference values.

For our survey on cyclist and car positions, we adapted the methodology used by the FHWA. Marks we made on the road at an interval of 0.4m and numbered (as shown in Figure 5). For the survey, one person was positioned on either side of the road and the positions of bikes and cars were recorded using Psion Organisers ('Psion'). The program used on the Psions' required a character to be entered (which was time-stamped) and then a number to be entered. For our survey the first character represented vehicle type ('B' for bike and 'C' for car) and the number was the corresponding number that the tyre nearest the kerb travelled over. The Psion results were downloaded and are in the form of a text file. The results were then imported into excel and the direction was added to each file. The results from each side were then collated, and calibrated. The analysis was done using MATLAB.

The nature of the data collection method results in data that has some limitations. For example if a car and a bike pass at the same time, one must be recorded before the other. The delay between the two entries is dependent on the speed in which the first entry is recorded. This inaccuracy caused issues when the data was analysed. The results are also affected by the use of two different Psions and two Psion operators in the survey (one Psion and operator for each side of the road). This experimental error was reduced by recording a test entry at the start and end of the survey and then calibrating the results using the difference in the test times. The error was also reduced by ensuring that the same operator recorded the same side during each surveys. The analysis also targeted same direction travel (with very little investigation done on the impact of cyclists travelling in the opposite direction to the influenced car).

For more accurate results an alternative method should be used. Use of a camera, for example, would allow for the moment to be slowed down when multiple vehicles cross the survey site. This would remove the errors associated with using the Psions.

3. RESULTS

3.1. Shared Pathways

Observations

The shared pathways at both Ilam Fields and Riccarton Bush appear narrow. Riccarton Bush has some shared pathway signs at each end. Despite this, it is still difficult to differentiate either pathway from a standard footpath.

Relationship between Path Width and Interactions

Our survey data was combined with data collected by previous studies to produce the relationship shown in Figure 6. To ensure compatibility between the data sets the old data was 'normalised' to our data set by comparing two pathways with similar volumes and widths. It was assumed that the difference in interactions between these data sets reflected the subjective difference within the survey collection method. The old data was scaled appropriately to better 'fit' the new collected data.

Figure 6 shows a clear relationship between the path width and the number on interactions per user on the pathway. As the path width decreases the number of interactions on the path increases. In practice this means that a path user will be more likely to have to change their positioning or speed on a pathway that is narrow. This relationship could be used as a design tool to give a rough estimate for required path width. A threshold value for interactions before a path was unacceptable was not established.

Federal Highways Administration

The FHWA shared path calculator can be used to assess the level of service of a shared pathway. A-C are considered acceptable and D-F are considered degraded levels of service (Federal Highways Administration, 2006). The results for the paths through Ilam Fields and Riccarton Bush can be seen in Table 1.

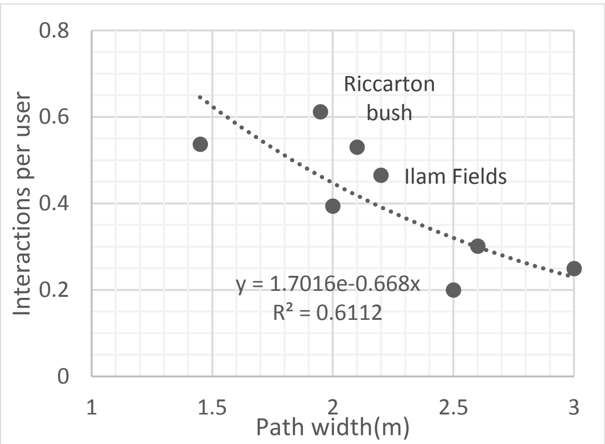

Figure 6. Relationship between interactions per user and path width.

In order to get a level of service of C (acceptable), Ilam fields would need to be 3.4m wide and Riccarton Bush would need to be 2.3m wide. However, the calculator was unable to determine an acceptable width for the peak volumes at Ilam fields or during the market at Riccarton Bush as they exceeded maximum width of the calculator.

It should be noted that the FHWA calculator has been calibrated using data from the United States of America.

Table 1. Level of Service

	User Perception		Trail Level of Service	
	Score	Grade	Score	Grade
Ilam (Average)	2.91	D	1.70	F
Ilam (Peak)	2.56	D	1.06	F
Riccarton (Average)	2.86	D	2.65	D
Riccarton (Weekday Peak)	2.87	D	2.67	D
Riccarton (Market)	1.67	F	0.17	F

ViaStrada

The shared pathways surveyed in this project can be seen plotted on the ViaStrada graph in Figure 7.

Ilam fields is currently 2.2m. The ViaStrada graph indicates that for the volumes at Ilam Fields a path of at least 3.0m is required. Riccarton Bush on the other hand is currently 2.0m wide. The demand for the path puts it right on the cusp of a 2.5m wide path. After the implementation of the Uni-Cycle route it is likely that the paths demand will increase and so the path may be found to be of insufficient width.

It should also be noted that the path demand on Saturdays during the local market, puts the path off the chart due to the very high pedestrian volumes. Therefore the path is not suitable as a shared pathway in the weekends.

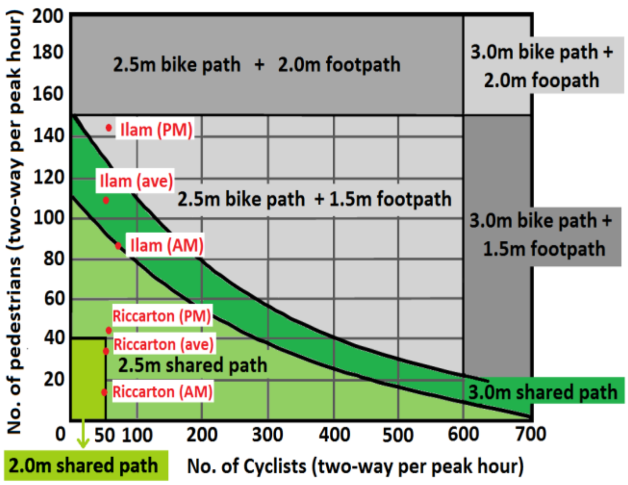

Figure 7. ViaStrada chart of shared pathway design

3.2. Neighbourhood Greenway

Overview

In this section the term 'influenced' refers to a car that is in the presence of a bike, and would therefore exhibit different behaviour to that of an uninfluenced vehicle. A car that is 'influenced' by a bike will be one that passes the same point within five seconds of a bike. This value was chosen as the cut-off. Given the observed speeds, five seconds corresponds to a vehicle within ~50m of a bike.

Observations

Hinau Street has a 'no parking' restriction on one side of the road during the academic year. During our surveys, all of the car parks on the other side were in use. The demand in parking is because the car parks are some of closest car parks to the university that do not require payment. As a result of the university driven traffic, we observed Hinau Street to have surges in volume every hour. This is because university lectures begin on the hour and so cars arrive and depart around this time. The nature of the traffic means that cars are travelling slowly as they search for parks. Low speeds are generally crucial for cyclist safety. However, as the drivers are also looking for a park they are distracted, which could negatively impact on cyclist safety.

Vehicle Speed

The vehicle speeds recorded, as shown in Figure 8, indicate that the average free speed of traffic is 38.8 km/h with a standard deviation of 8.4km/h. This value is reduced in the presence of a bicycle, most dramatically when the bike is travelling in the same direction as the car. In this case the average speed of the vehicles is 36.8 km/h with a standard deviation of 8.7 km/h. A difference in mean values of 2 km/h is relatively small compared to the standard deviations of the distributions. But this small difference, when combined with other factors, contributes to the suitability of the street. The survey had a large sample size (~6000 for uninfluenced, ~200 for influenced by the same direction) making the results reliable. A small reduction in speed when in the presence of a bike is important for a safe cycling environment.

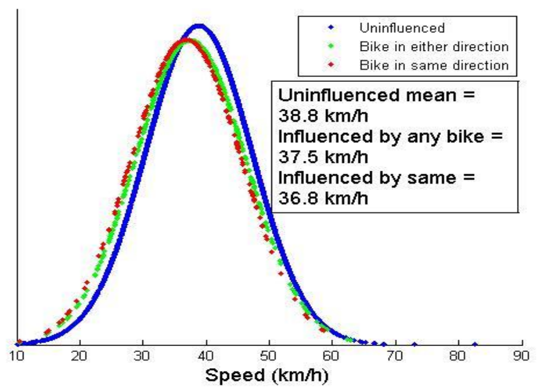

Figure 8. Normal distribution of speeds with uninfluenced and influenced speeds

International literature recommends vehicle speeds below 25 mph (~40 km/h) for a neighbourhood greenway (Cross County Connection Transport Managment Association, n.d.). However, CCC are aiming for speeds below 30 km/h (Christchurch City Council, 2013). The observed mean speeds are seen to be around 40 km/h. As this indicates that half of the traffic are travelling above this speed, traffic calming devices would likely be required to reach the Councils goal.

Vehicle Volumes

From the MetroCount data the 'Annual Average Daily Traffic Flow (AADT) was found to be 1200. The Christchurch City Council recommends volumes of less than 2000 AADT for shared lanes. The 'Bike Way Design Guide' (Cross County Connection Transport Managment Association, n.d.) recommends volumes of less than 3000 AADT for shared lanes. Our data meeting both low volume criteria, supporting the use of Hinau Street as a neighbourhood greenway.

Vehicle Position

The survey results showing the vehicles position relative to the kerb can be seen in Figures 9 and 10. The graphs indicate the position of the cars kerb-side tyre. The graphs show vehicles that were influenced by cyclists travelling in the same direction of travel as the car and may include vehicles that were following cyclists.

Figure 9 shows that, for cars heading towards the city, cars are further from the kerb when in the presence of a cyclist. The results show that the cars moved an average of 20cm. The cars ability to shift is restricted by the opposing traffic.

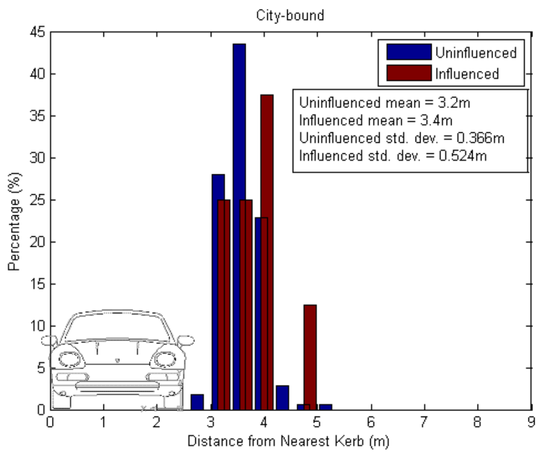

Figure 9. City-bound car positional data

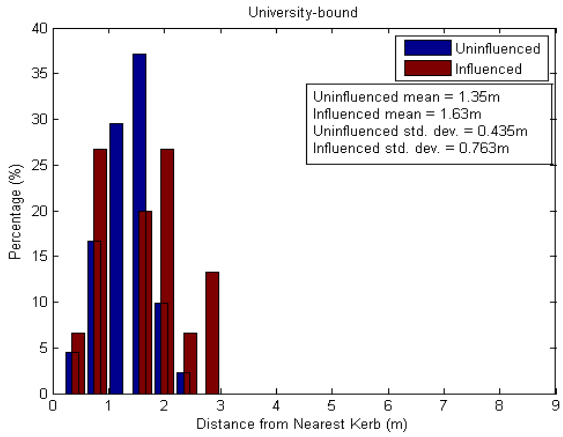

Figure 10. University-bound car positional data

Figure 10 shows the position of the cars heading towards the university (the side of the road without car parks). The cars were seen move over an average of ~30 cm when influenced by the presence of a cyclist. The results however also have an increased number of vehicles much closer (0.8 m) to the kerb. We hypothesized that this may be due to vehicles that were following cyclists. However, the results were inconclusive due to limitations of the survey.

Separation Distances

The amount of space provided by a car when passing a cyclist was determined using the positional data. The average separations are indicated in Figure 11. City-bound vehicles were seen to give an average of ~1.6m between themselves and a cyclist. University-bound vehicles on the other hand were seen to give an average of ~1.7m between themselves and a cyclist. The New Zealand Transportation Authority (NZTA) recommends that a car allows 1.5 m of space when passing a bike (New Zealand Transport Agency, 2013). As the values stated above are average values, this indicates that half of the cars are providing the cyclists with insufficient space. This could however, be a result of experimental error which is greatest when multiple road users crossed the survey area within a small time period. As this is when separation data was most important, as the vehicle is in close proximity to a cyclist, then this may have affected the results. Driver behaviour could be combated by driver safety campaigns.

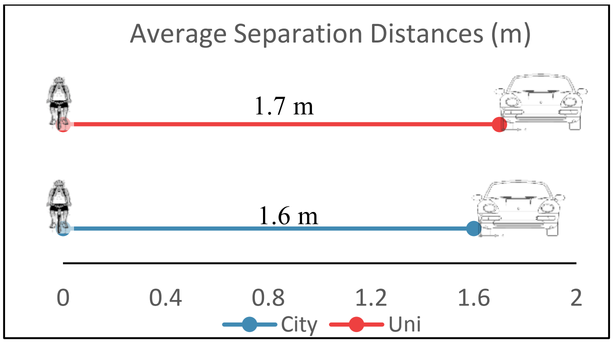

Figure 11. Average Separation Distances

4. PERCEPTION SURVEY

4.1. Overview

An online perception survey on cycling infrastructure was prepared. The survey was conducted online using Qualtrics survey software.

The survey was distributed on social media and other online forums and collected 149 responses. It was used to determine how suitable the Uni-Cycle route is and how comfortable people would be using it. Questions investigated what infrastructure changes could be made in order to improve these perceptions. The changes included adding road markings and signage.

4.2. Potential Bias

The nature of an online survey means that there is a large potential for some bias. This bias occurs when some people are over-represented in the survey population which can cause the results to vary from that expected. To investigate this bias the survey population was split into representative groups; e.g. male vs female, student's vs full time workers etc. By comparing the results of these groups any bias may be identified. The identified biases are discussed below.

How frequently a survey respondent cycles has an impact on their response. In particular for shared pathways, where being a regular cyclist made the responses more positive.

The impact of student responses compared with non-students was investigated. This was because the survey had a large number of responses from students. The responses showed that working status had little effect on the responses given.

Approximately two thirds of the responses to the survey were male. The responses of males compared to females indicates that males, on average, thought that the pathways and roads were more suitable for cycling than compared to females. The same trend was found for how comfortable the participants thought they would be using the facility. This result is often mirrored in other cycle perception studies.

4.3. Survey Results

The online perception survey found that:

- The presence of parking along the road makes a road less comfortable to bike down as well as making the road appear less suitable
- The addition of road markings or a sign indicating a shared space slightly increases the perceived suitability of the road for cycling
- A wide path is considered much more suitable than a narrow path for a shared pathway
- The addition of a centreline makes a path more suitable for a shared space

- When a centreline is present, additional markings such as direction of travel and intended uses should be included

5. RECOMMENDATIONS

5.1. For Uni-Cycle Route

As a result of this study the following recommendations can be made:

- Increase width of Ilam fields by at least 0.8m
- Add centreline and other markings to shared pathways to increase comfort levels
- Add road markings to Hinau Street to improve perceived suitability and comfort

5.2. Opportunities for further research

There is an opportunity to develop the model for the relationship between width and interactions. Our study was limited by time constraints but further work would enable a better model to be developed which would provide a better, New Zealand specific, model which would be an alternative to the existing industry tools.

In order to gain more accurate results when assessing neighbourhood greenways, we would also recommend using video equipment instead of Psion Organisers in order to reduce experimental error.

6. CONCLUSION

The shared pathways were found to be of insufficient width for their respective demands. The FHWA model recommends a width of 3.4 m for Ilam Fields and a width of 2.3 m for Riccarton Bush. The ViaStrada model on the other hand recommends a width of 3 m for Ilam Fields and 2.5 m for Riccarton Bush. However, neither of these models have been calibrated for New Zealand pathways and should be taken as an indication only.

The neighbourhood greenway was found to be suitable as it had low vehicle speeds and volumes. The average vehicle speed was 38.8 km/h which is less than the 40 km/h threshold. Hinau Street was also found to be a low volume street. The vehicles were also seen to provide sufficient distance when passing cyclists.

Our perception survey found that the presence of parking along the road makes users feel less comfortable and suitable for cycling. We also found that the addition of road markings or a cycling sign slightly increased the perceived suitability of the road for cycling. A wide path was considered much more suitable than a narrow path for a shared pathway. A centre line on a shared path was also preferred. When a centre line is present additional markings indicating direction of travel are also preferred. This study has shown that there is a lot of work to be done with regards to the design standards of shared pathways in New Zealand. Current design tools are not calibrated to New Zealand conditions, and developing national design tools should be a high priority. This study has also shown that there is an opportunity to utilise quiet residential streets as cycling routes in the form of neighbourhood greenways. It is likely that there are many streets throughout the country similar to Hinau Street. Identifying these streets and utilising them in future cycling networks should be encouraged.

7. ACKNOWLEDGEMENTS

We would like to acknowledge Dr. Glen Koorey for his guidance on our project.

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