Multiple Criteria Bicycle Route Assessment

Integrating Demand, Supply & Stakeholder Perceptions for a Spatial Decision Support System in Christchurch, New Zealand

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March, 2015

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Enschede, The Netherlands, March, 2015

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
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ABSTRACT

This MSc thesis is working towards the creation of a bicycle route assessment which can incorporate demand and supply data for input into a participatory Spatial Decision Support System (SDSS), with a test of its application in Christchurch, New Zealand. This thesis proposes a cycling program which is responsive to needs and preferences of different target cyclist groups as identified by policy makers. It exemplifies how target groups such as current cyclist commuters, potential cyclist commuters, and parents of children aged 10-17 can have their needs and preferences of various bicycle-friendly ideals ranked, then how these aggregated group preference sets can be turned into weights and applied to roadway performance measures. These preferences allow infrastructure project designers to forecast how much their investment is likely to improve the bicycle-friendliness of any given junction, segment, or route. Outputs of the assessment give detailed information which can be used to see how much overall bicycle-friendliness benefits after the worst-scoring route components are targeted with improvement projects.

Prior to their incorporation into the SDSS, each Christchurch target group was analysed for their current mobility patterns and feelings in regards to cycling in their neighbourhood. Census results and July 2014 surveys revealed the population to be relatively unresponsive to the efforts of past cycling programs. Many Christchurch residents believe they live within a cyclable distance from work/study, but the car remains their main mode of transportation to work/study. Stakeholder analysis revealed public dissatisfaction with Christchurch's current cycling program and difficulties with current roadway design. Stakeholder analysis suggested a variety of improvements for behaviour, connectivity, maintenance, present facilities and current design, navigation, and for obstructions/poor visibility. However, improvements suggested by the public in the past were perceived to not be reaching roadway designers and past policies were not always thought to be in accordance with the public's stated needs. Considering these results, a more comprehensive program may be necessary to effectively increase the bicycling modal share in Christchurch and similar cities.

This thesis argues how an assessment (which can take quantitative road measures, apply them to target group weights, and output useful information for bicycle route designers, engineers, and policy decision makers) can become the structure for such a comprehensive policy program. Evaluation of the test area results support the theory that inherent conflicts exist between bicycle-friendly criteria. These results confirm route assessments must take into consideration the proper scale and detail for which they should be applied. Small areas only require junction and segment assessment, while large areas are suitable for route or network-level assessment. All of these are possible with the scalable formulas proposed in this paper. In the long-term this assessment procedure could provide a platform for the application of quantitative and spatial standards proposed by national and regional policy makers, subsequently structuring the pre-project process and improving the overall quality of New Zealand urban bicycle networks.

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1. INTRODUCTION

1.1. Background and Significance

Developing infrastructure for a population with diverse needs and interests is a complex process and bicycle facility designers must use their expertise to balance often conflicting ideals. In New Zealand there is no legally regulated process for the planning, design, and implementation of bicycle facilities and the quality of regional cycle projects is dependent upon the experience and judgements of the locally-available experts. However, a legally regulated process may be within reach. South Island urban areas have extensive data collection and research on individualized population dynamics, infrastructure supply measurements, and demand forecasting. These are dimensions which are widely recognized for their importance to transportation systems. A weakness of New Zealand professional practice is these three dimensions are not always integrated prior to bicycle infrastructure implementation. To strengthen the New Zealand planning and design process, this thesis begins the development of a multiple criteria bicycle route assessment procedure for Christchurch, displays how it can be used on a street and junction scale in a test area, then discusses the implications and how the route assessment can be scaled to whole city networks.

1.1.1. MCA as an SDSS for Bicycle-Friendly Infrastructure

This study defines a criterion as a standard of judgment or rule on the basis of which alternative decisions can be evaluated and ordered according to their desirability (Malczewski, 2006). A criterion will show what is and is not allowable for an infrastructure project and the criterion's success is evaluated by performance measures. MCA (Multiple Criteria Analysis) is a technical tool to be applied in decision-based assessment procedures whose results can then be used to support legal and institutional procedures—such as Environmental Impact Assessment or Cost Benefit Analysis—required by law (Flacke, 2014). This study considers GIS (Geographic Information Systems) as a spatial decision support system which provides a platform for spatially referenced datasets and theoretical evaluation techniques such as MCA.

Supported by bicycle-friendly categorization systems as proposed in international best practice guidelines (CROW, 2007; NZ Transport Agency, 2009), MCA allows the use of traditional engineering bicycle-friendly measures while still allowing individuals to define their preferences. The advantage of MCA is its capability of using hierarchical preference sets, thus giving initial relationships to the criteria before ranking their importance. In general, Factor Analysis and Regression models do not use hierarchies which could be defined by the road-users themselves. The importance (of road-users being able to state their own preferences, thus taking more ownership of the spatial decision making process) will be discussed in in the coming sections.

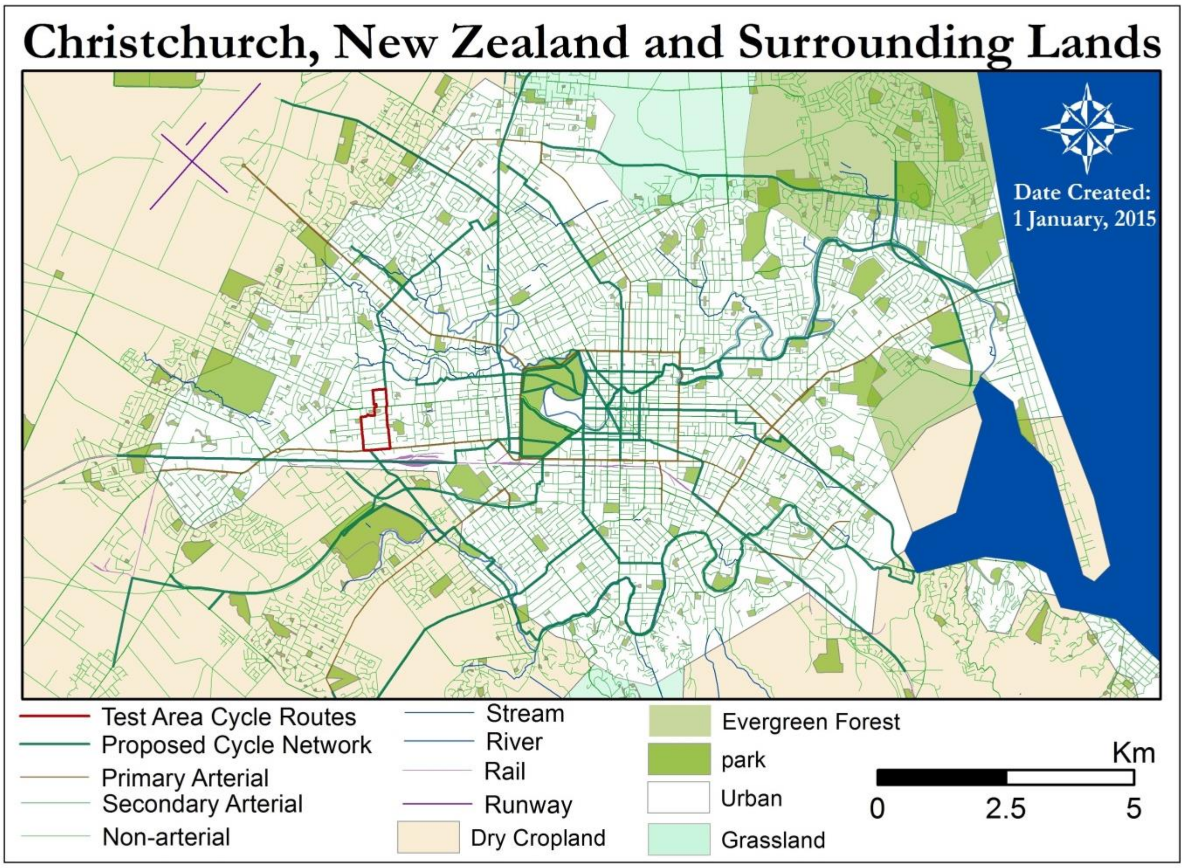
MCA is highly applicable to evaluation, comparison, and prioritization of proposed transportation routes. Through performance measurement, standardization, and weighting (of the multiple criteria by their relative importance to a certain preference set) similar route options can be analysed and compared to find which is the most suitable to each stakeholder group and their related policy visions or managerial objectives (Keshkamat, Looijen, and Zuidgeest, 2009; M. A. Sharifi, 2004). MCA has potential to structure the New Zealand bicycle-friendly infrastructure planning, to keep it locally relevant, and to support the decisions of policy makers and facility designers.

1.1.2. Christchurch Status and Policy

The 2010 and 2011 earthquakes put New Zealand in a national state of emergency and left much of Christchurch damaged. Specifically, 52 percent (1,021 km) of Christchurch's total urban sealed roads required rebuilding. Of these damaged roadways, only 27 percent has been repaired or replaced as of June 2014. The most severe damage is concentrated in the Central City and east of Hagley Park. There is extensive and moderate road damage in the South of the Port Hills and north of Kaiapoi (SCIRT, 2014).

For the rebuild, Christchurch's strategic transportation plan has set a goal to improve access and modal choice. According to the 2010-2013 New Zealand Household Travel Survey, cycling only covered 3% for mode's share of trip legs (Ministry of Transport, 2014a) and cycling only covered 9% of Christchurch's MUA (Main Urban Area) mode's share of journeys to work (Ministry of Transport, 2014b). To increase their cycling modal share, there are plans to rebuild the road infrastructure to suit a well-connected, safe bicycle network. Parts of the bicycle network are already developed, but there are many problem areas requiring in-fills. As the city's finances are strained (Christchurch City Council, 2012), there are low funds for separated bicycle path construction and on-road bicycle lane projects will likely be prioritized. Arterials will also likely be preferred as they have enough space to easily accommodate the addition of bicycle facilities. The national cycling network and planning guide encourages this, arguing arterials are the most direct and will likely be in accordance with travellers' desired route (Land Transport Safety Authority, 2004).

Figure 1 Map of Christchurch, the Test Area, & Surrounding Lands



In Christchurch these problem areas will be undergoing some form of route assessment, though New Zealand bicycle facility planning is not always a systematic and comprehensive process. As the national cycle network and route planning guide states, "A perennial problem in cycle route network planning is the reliance on bright ideas and pet projects that may not have been critically evaluated for usefulness and value for money." Similar to any other publicly-funded infrastructure project, bicycle routes should have assessment and review before being finalized (Land Transport Safety Authority, 2004). A lack of these can cause problems. Even when bicycle facility designers foresee severe consequences to a given transport project, if they do not have systematic evaluation methods they might not be able to estimate local impacts or justify the preventative measures (Beukes, Vanderschuren, Zuidgeest, Brussel, and Van Maarseveen, 2013) which they feel are needed.

New Zealand bicycle facility planning and design is a process in development; the advised standards which exist are quite flexible and are sometimes coming from outdated guides. As of 2004, the New Zealand supplement to *Austroads Guide to Traffic Engineering Practice: Part 14 Bicycles* from Transit New Zealand, became the main design guidance tool for cyclist facilities on roads and paths (Land Transport Safety Authority, 2004). This guide and its more recent editions appear to only cover basic level of service measurements. Additionally, the LTSA (Land Transport Safety Authority) 2004 *Cycle Network and Route Planning Guide* states how their advice for desirable facilities in relation to standard criteria like traffic volume and speed are not always useful. But that, "in practice, constraints on space, presence of side roads and driveways, type of users and costs will also dictate the choice of facilities to retrofit to existing situations" (Land Transport Safety Authority, 2004). The aim is to provide convenient cycle routes with the highest level of service, which offer adequate operating space and minimize conflict between different road users. Official cycle routes should provide safety, comfort, directness, cohesion, and attractiveness. The 2004 LTSA guide stresses the importance of infrastructure for locally identified risk factors, but does not go into detail on how to identify these risks, nor how to plan for their mitigation. They propose a supply-side approach for assessing LOS (Level of Service) which the authors thought to be appropriate for New Zealand. The document admits latent demand is another area requiring more work. According to this 2004 LTSA guide, "All options identified should provide cyclists with an appropriate LOS and must be feasible and provide value for money", a mix of methods are suggested yet it does not detail how cities should assess one route project over another. The 2004 LTSA guide further states, "Individual RCAs (Road Control Authorities) are encouraged to consider implementing a cycle audit, and cycle review style of process, and to work with the LTSA to develop a New Zealand recommended process". For this the two most important aspects identified are: 1) if facilities meet the users' needs; and 2) if junction features can be resolved to accommodate the cycle route. In this direction, the 2004 LTSA guide makes a distinction between different cycling target populations, stating routes should not only link together and form a network to retain existing cyclists, but should also encourage more people to start cycling. Little detail or review is given on methods for pre-project assessment and further investigation is encouraged (Land Transport Safety Authority, 2004).

The policy goals of Christchurch are in accordance with these national guides. Appendices G and J of the *Canterbury Regional Land Transport Strategy 2012-2042* state the statutory 2024 target is to increase time spent walking and cycling to 100 hours per capita per annum within Christchurch city. By 2042 they hope to increase this to 150 hours. Right now, the committee reports baseline data suggesting current activity levels are around 70 hours per annum, including 60 hours walking and 10 hours cycling. The document also states they wish to improve people's feeling of safety while cycling in Canterbury, but they do not set any targets. In order to achieve Canterbury's regional outcomes over the next 30 years, the report states investments will be shifted from providing additional road capacity towards optimizing what is currently available and to increase investment in walking, cycling, and public transport. Specifically, in the next 4-12 years they are building a "comprehensive network of rapid cycle lanes, priority measures and local links" to be provided on the road network. Appendix J of this report states they wish to reduce the cycle-related casualties and serious injuries per annum, which is currently around 9% of all road casualties. The report goes on to further claim traffic control signals on non-strategic roads will increasingly support multimodal use with less emphasis on efficiency for motor vehicles. Road space will be increasingly managed to have the following priority order: pedestrians, cyclists, public transport/freight, high occupancy motor vehicles, single occupancy motor vehicles (Canterbury Regional Transport Committee, 2012). There is no mention of estimating future demands and placing cycleways where these demands are highest. The report only mentions investments in cycle lanes will hopefully decrease roadway congestion and help better manage demand. The committee proposes attitudinal and behavioral measures will encourage drivers to consider modes such as cycling and walking, thus freeing up their current road supply. A picture of their roadway supply and demand strategy can be found in the back of this thesis document in Appendix A, Part 1.

The Canterbury Regional Transport Committee states physical activity has been reducing and that a need exists to encourage a greater proportion of the population to walk and cycle. Their 2012 report states cycling must become a greater part of people's everyday life and how "workplaces and schools (in the Greater Christchurch area) will be encouraged to adopt cycle-supportive policies" (Canterbury Regional Transport Committee, 2012). Hence, current (cyclist) commuters, potential (cyclist) commuters, and children are target groups for increasing cycling's modal share. They claim greater levels of investment will provide more choices to the region's population, and from what can be read, they believe the population will start utilizing these facilities once they are provided with them. Christchurch City Council (2012) has stated different assessment criteria will be preferred depending on the different combinations of cyclist types and trip types. However, the city has not publicly addressed how the needs and preferences of these different target populations will be weighed against each other and chosen. This will be an issue since the threshold for cyclist safety and comfort is a function of both traffic speed and volume, and varies for each cyclist's trip purpose and personal skill, physical capacity and experience (Transit New Zealand, 2008; CROW, 2007).

Their goals and road designs are based on universally accepted supply-side criteria, yet provision of these infrastructure standards may not be enough to significantly increase the city's cycling modal share. Integrating supply and demand-side criteria, and then using these to appeal to target populations (children, commuters, etc.), will likely provide a methodology with better results. Using this as a part of the assessment methodology is especially relevant since it is suspected cyclist views and concerns vary per target population. For New Zealand, this difference in perceptions is compounded by what non-cyclists hear in the media regarding recent cyclist deaths. If people do not cycle frequently, they may not have a proper understanding how safe most roadways can be. Thus, facilities which are specifically aimed at attracting these new, more hesitant cyclists will likely prove more encouraging for this target group, and may overall prove to be more effective for increasing the cycling modal share.

1.2. Research Statement

1.2.1. Problem

Christchurch's current SDSS needs an integrated bicycle route assessment procedure which combines stakeholder perceptions and criteria from both supply and demand-side models to assess routes suitable for their citizens and their city. This requires research to identify bicycle-friendly criteria and to formulate an assessment procedure with a demonstration of its application to finding suitable bicycle-friendly roadway segments and junctions which can form routes within the city's transportation network.

1.2.2. Objectives

The main objective is to design a bicycle route assessment integrating demand-side criteria, supply-side criteria, and stakeholder's perceptions of bicycle friendliness, the results of which can be applied in a Spatial Decision Support System. Specific objectives include:

1) To review currently used methods and choose criteria relevant to the study area's bicycle network goals, planning policy, engineering standards and managerial objectives.
2) To integrate the chosen criteria within a new procedure and apply them to the study area.
3) To evaluate the procedure and its assessment results.
4) To discuss the implications these could have for bicycle route planning.

1.2.3. Questions

Table 1 Sections Covering Research Questions

Specific Objectives		Research Questions	Covered in Sections
1	Review & Choose	What are the local goals and policies which could drive bicycle route assessment?	1.1.2
		Which criteria from traditional demand-side assessments are relevant?	1.3
		Which criteria from traditional supply-side assessments are relevant?	1.3
		Are there some criteria which could influence perceptions or determine behaviour, and in what ways can these be transformed into spatial criteria?	1.1.1, 1.3
		What ways can these criteria be measured and integrated?	2.3, 2.4.2, 2.4.4
2	Integrate & Apply	Which kind of problem areas within Christchurch require bicycle route assessment and can they be categorized and prioritized based on which would most benefit from assessment?	2.4.1
		Which target cyclist groups can be accommodated by the problem area's route?	3.1
		Are there hazards of the test area which must be included as constraints into the route selection and assessment?	2.4.1
		How do assessment results change when the criteria weights are modified to suit different target cyclist groups?	2.4.5, 2.4.6, 3.2
3	Evaluate	For each target cyclist group, how do the different criteria compete with or complement each other?	3.2.1, 3.2.2, 3.2.3, 4.1
		Is there a route which performs well for multiple target cyclist groups?	3.3
4	Discuss	Did any general trends emerge about why some routes perform better than others?	3.3, 4.1
		Were the criteria sufficient to cover the different target cyclist groups?	4.1
		What are the limitations and deficiencies of this assessment procedure?	4.1.1, 4.1.2
		Can this assessment procedure be applied to other problem areas within Christchurch's Network?	4.2
		Can this assessment procedure be used as a model for other cities?	4.2

1.3. Multiple Criteria & Stakeholders—A Review

MCA, factor analysis, linear regression, and similar transportation planning tools have been applied to assess bicycle facilities, but their criteria are split into two distinct areas of research: demand-side and supply-side analysis (Rybarczyk and Wu, 2010). Few have integrated these two and even fewer bicycle route assessment procedures involve stakeholder perceptions from the beginning of the assessment procedure. In traditional facility planning, these demand and supply criteria and their assessment weights were based on expert opinions, which was acceptable so long as the problem was very well understood. However, the presence of either fuzzy or probabilistic uncertainty creates more complicated decision problems which are harder to model with accuracy (Malczewski, 2006; Mendoza and Martins, 2006).

Beukes, Vanderschuren, Zuidegeest, Brussel, and Van Maarseveen (2013) discuss how complex contextual problems are often unsupported by traditional transportation planning assessments. Though roadway design requirements and operational parameters are usually based on transportation demand models, these are criticised because the results focus designers on providing capacity. Projects born from these traditional assessments have unintended consequences for closely related systems, leaving negative effects on the economy, environment, and society. According to the authors, there is widespread acknowledgment of these negative impacts though little has changed in professional transportation planning. Beuke and his colleagues propose an MAVT (Multiattribute Value Theory) decision analysis method which supports multiple modes and better integrates demand and land use. The study validates the core theme how certain roads are more appropriate for certain modes. However, there was not much discussion on the specific consequences which might be placed on cyclists if they use a given road with vehicles. Furthermore, while they researched various bicycle-friendly infrastructure, they did not account for design of facilities for different target cyclist groups (children, potential cyclist, new cyclist, experienced, etc.).

Many studies have analysed how different urban populations' choice to cycle links to the cumulative impacts of bicycle facility infrastructure design, built environment urban design and land-use diversity dimensions (Cervero and Kockelman, 1997; Wardman, Tight, and Page, 2007; Parkin, Wardman, and Page, 2007), yet the non-integrated nature of most of these studies limit their results. Although they show how built environment factors (such as intersection design, mixed land-use, block size, gridiron streets, proximity and density of retail/service activities, etc.) can strongly predict the probability of a trip being made by bicycle, stronger evidence is needed if cities want to successfully increase the modal share of non-motorized travel (Cervero and Duncan, 2003). Pucher, Dill and Handy (2010) reviewed 139 studies of bicycle interventional programs and gave an in-depth review of 14 case studies. Generally, substantial increases in bicycling only occurred in cities with comprehensive strategies targeting not only infrastructure provision, but pro-bicycle programs, supportive land use planning and restrictions on car use. Their review shows car dependent societies face additional challenges to increasing cycling and how provision of well-placed bicycle-friendly infrastructure is not enough to induce a non-cycling population to choose cycling in the future.

There have been many past comprehensive bicycle planning studies. Land use and transport have long been known to affect each other, so it is little effort to see how major arterial roadways have elevated demand potentials. This relationship was confirmed by Rybarczyk and Wu (2010) when they completed an MCA using GIS for the CBD of Milwaukee. Also, using the safety measure of BLOS—which tends to favour local and collector roads for their bicycle-friendly traffic and infrastructure conditions—they found a stark conflict between high demand routes and the supply-side safety criteria. They looked at this relationship on different scales and discovered a spatial autocorrelation for potential travel demand on the neighbourhood scale, a trend which did not happen at the network scale as there is less homogeneity in land use. Importantly, this indicates a criterion changes with scale and with the type of roadway which is being considered. It also implies there is inherent conflict between desirable bicycle-friendly criteria. However, the more precise relationships between criteria on a link and node (non-aggregated) level is still unknown. As pointed out by Rybarczyk and Wu (2010), detailed link and node assessment is necessary as micro-environments are important to cyclists and more research is needed. A weakness of Rybarczyk and Wu's work is they were the ones making the expert judgments about what the cyclists would most prefer. This is problematic because it may not be a proper representation of the road user's decisions.

Understanding local behavioural determinants and perception drivers could be a crucial step for a city's bicycling success. Heinen, van Wee, and Maat (2011) found psychological factors and personal attitudes have a relatively strong impact on a traveller's choice to commute by bicycle, with the most import identified factors were safety and awareness for long distance trips. Short distance trips were also influenced by perceived opinion of others, and the decision to cycle every day was due to the perceived direct benefits to their health and the environment. They also found there to be significant differences between cyclists and non-cyclists, and between full-time and part-time cyclists. Their study is limited because it did not investigate non-commuter trip purposes like recreational or other utility-based trips. These utility trips are usually for everyday errands, which are often made with high frequencies and over shorter distances, and including them in the study would likely have changed the results. Furthermore, it assumed the built environment does play a role in individual attitudes, though it did not include this as a variable. Nonetheless, their findings are still relevant and are generally supported by the worldwide cycling literature.

Though observed travel behaviour is more reliable for demand studies, Börjesson and Eliasson (2012) relate how marginal utilities cannot be observed directly and how we must expect they are affected by the traveller's and the trip's characteristics. As they state, "the resource value of time should increase the less available time the traveller has in general." The availability of time is also affected by variables such as mode and employment. And in general new and non-cyclists are expected to have different values of time than those people who are experienced and regular cyclists. While they point this out as being a deficiency for Cost-Benefit Analysis of road infrastructure, their results do not show exactly how influential varying time values can be. And even though they discuss monetizing the public benefits of increased cycling, they do not account for how the public's cycling image and general perceptions (or needs or preferences) may decrease the efficiency of the policy goals they are analysing. A Sydney-based study supports the influence of perception and image, where Daley and Rissel found respondents had an acceptability hierarchy in regards to cycling. Recreational cycling was most accepted (perhaps because it was most common) and transport/commuter cycling was one of the least accepted due to perceived rule-breaking and risk-taking activities (Daley and Rissel, 2011). Neither of these studies discuss the transferability of their findings, or their applicability for assessment of other cities, but they still are useful for identifying how perceptions of bicycle-friendly criteria varies. They also highlight the potential importance of the general public's opinions.

Each year the scientific community becomes better at understanding the road users, but integrating them as stakeholders into an assessment procedure is still not a straight-forward process. Many participatory methods assume a homogenous community (Mendoza & Martins, 2006), which as shown above is not the case for those populations which might be targeted by cycle infrastructure programs. As Geneletti (2010) states, building consensus around a decision, reducing conflicts, and paving the way for successful projects require both technical elements and the people's values and perceptions to be taken into account. Current bicycle facility planning and its comparison of alternative routes is often not systematic with its incorporation of policy goals and stakeholder participation, but largely dependent on the experience of a few experts. To improve this, a large number of public stakeholders could be engaged and their feedback aggregated to give their overview of the problem and to weight the criteria (Mendoza & Martins, 2006). Thus, enhancing the predictability of how the project will be used once it is complete.

From 1990 to 2004, Malczewski (2006) reviewed and found the transportation studies which incorporated GIS and MCA were limited mostly to vehicle routing and scheduling, with only a few cases of roadway routing and very few concerning the routing of bicycle facilities within an urban region. Traditionally, a good deal of transportation-related MCAs were for Impact Assessments (Janssen, 2001) and, though their extensive use in countries like the Netherlands has indeed made the decision process more transparent, the importance of the MCA results is not always clear and directly relatable to what the decision makers need for the final decision (Hajkowicz, 2007). Along with this, Janssen found the final chosen alternative is usually not compared to the original alternatives used in the MCA. This means there is little post-assessment evaluation and not much feedback to improve the assessment procedure unless an explicit effort is made to do so. While EIA procedures have improved since Janssen's 2001 report (Hajkowicz, 2007), this still seems to be a problem with transport pre-project evaluations as the results of one MCA do not necessarily influence the alternatives chosen for the next. As (Janssen, 2001) states, "Methods should be developed to provide more systematic support for building a consistent evaluation framework".

While extensive conceptual and operational validation has been studied in the field of MCA, many GIS studies have incorrectly used the procedures or used stringent assumptions which are hard to support in the real world (Malczewski, 2006). Pomerol and Barba-Romero (2000) give extensive reviews for each major branch of MCA and they delineate two ways of looking at decision problems: 1) with ordinal data which only include the order of importance placed upon the criteria; and 2) with cardinal data which are open for compensation and thresholds to be placed. Involving the public into the MCA is difficult for cardinal (quantitative) procedures because a great deal of questions is typically needed and these questions are not always easy to answer. Due to its capacity to consider uncertainty and specific valuation between each criteria pairwise comparison is one of the better respected methods. It was used for transportation (M. Sharifi, Boerboom, Shamsudin, and Veeramuthu, 2006), however it is time intensive and requires stakeholder input to evaluate the difference between each criteria. This is excellent for experts who would be expected to have well understood frameworks and consistent answers. However, normal citizens who are participating as stakeholders may not have the training or experience to have developed a set framework for thinking about these problems. For these people, it is almost certain some of their stated preferences will be inconsistent. Less complicated measures are better for these large groups of non-experts, because even if they do not know the exact importance of one criterion, they do know its general importance and can rank them with fairly high certainty (Boerboom, 2014). When their results are aggregated (and if the group is large enough), these minor inconsistencies will balance through the averaging (Pomerol & Barba-Romero, 2000). Furthermore, techniques which require extensive questioning can cause fatigue or decreased participation, and the questions may be left uncompleted or unrepresentative due to poor mood. This means for any method with large numbers of criteria, any method requiring precise decision matrices like Pairwise comparison will require impractical amounts of stakeholder questioning (Pomerol & Barba-Romero, 2000).

This problem is not so important according to some. Hajkowicz and Higgins (2008), well as others (S. A. Hajkowicz, 2008; Pomerol and Barba-Romero, 2000), recognize different ranking techniques often change MCA results only slightly and it is advised to put greater focus on structuring the decision problem (option/alternative identification, choosing the right criteria, and determining an appropriate weighting method).

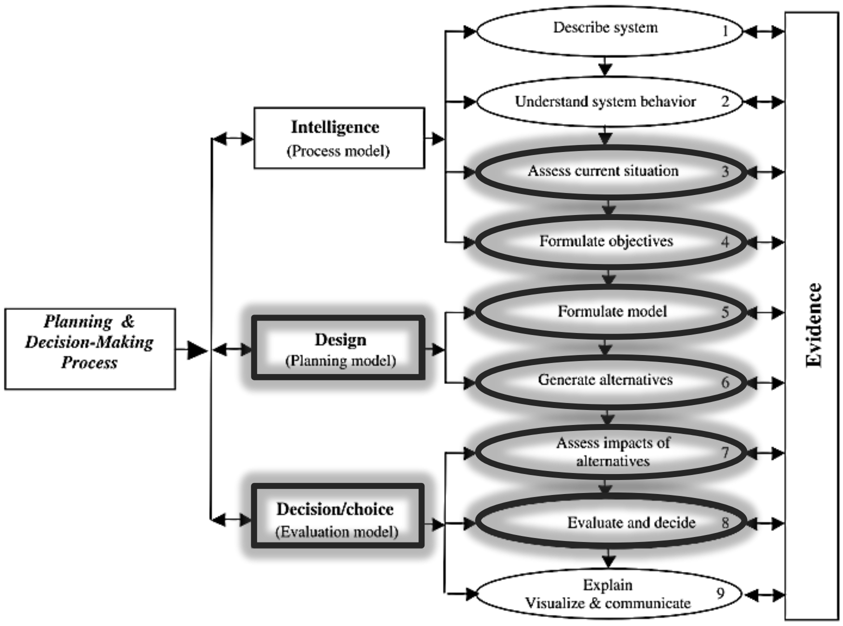
Once each stakeholder ranks the criteria, these preference sets must be aggregated. Yet there is disagreement on how to do this as Arrow's Theorem states there is no way to fairly and logically aggregate individual preferences over three or more alternatives (Mendoza and Martins, 2006 ; Pomerol and Barba-Romero, 2000). However, de-aggregation has its own problems and is not effectual in real group problem solving situations. This is why, despite its limitations, aggregation is commonly used. Models include voting, utility functions, parentian analysis, game theory, Analytical Hierarchy Process (AHP), AHP Fuzzy Set Theory, and public value forums. Mendoza and Martins (2006) describe aggregation as becoming more acceptable with higher homogeneity in the decision making groups. The highest homogeneity of course would come from a factor analysis of the preference sets, then aggregating and grouping them based off of their like-minded opinions, but this is not practical for applying in local government and for advising bicycle route designers. Therefore criteria remain policy-based and perfect homogeneity in assessment target groups remains an ideal to be strived for.

2. METHODOLOGY

The last chapter discussed the basics of MCA and covered the findings and limitations of past bicycle studies. It discovered how changing scales could impact results, how both scale and location dictate criteria relevance, and it clarified when aggregation of group preferences is realistic (i.e. presence of homogeneity and a need for public input). This chapter will step into the deeper theories behind MCA and will designate suitable techniques for the decision problem at hand. Following the conceptual framework and research design, there will be a presentation of the criteria performance measures and the test area within Christchurch, and then an explanation of the analytical process.

2.1. Conceptual Framework

Figure 2: Framework for Planning and the Decision-making Process (Sharifi and Rodriguez, 2002)



Spatial Decision Support Systems (SDSS) lend flexibility to decision-making by providing mechanisms for the input, representation, and analysis of complex spatial data in a variety of easily visualized forms. Assessments made for SDSS are iterative, integrative, participative, and adaptive to the new capabilities which best fit the decision problem at hand (Densham, 1991). For discrete decision problems with a given choice set of several options, the options are evaluated based on their characteristics or attributes. None of the options can be deemed the optimal choice, but one can be chosen as the most suitable to fit certain perspectives and their specific needs. By framing attribute information from the perspective of the decision maker, such as their policy vision or managerial objectives, these attributes become value-based criteria (Pomerol and Barba-Romero, 2000). The criteria in turn are capable of assessment in the pre-project planning phases (Sharifi and Rodriguez, 2002). This thesis will span Sharifi and Rodriquez's three process stages, with a special focus on the model formulation, generation, assessment of alternatives, and evaluation. Besides what was reviewed in the last chapter, the scope of this study will not include in-depth knowledge gathering of the travel behaviour system, nor will it make the final decision. The thesis aims to design an assessment procedure for bicycle routes, and tests its application in Christchurch, NZ. For comparison, see New Zealand's "best practice" bicycle facility planning process (Appendix A, Part 1).

2.2. Research Design

The research design is formed directly from this study's four specific objectives, shown in the diagram below.

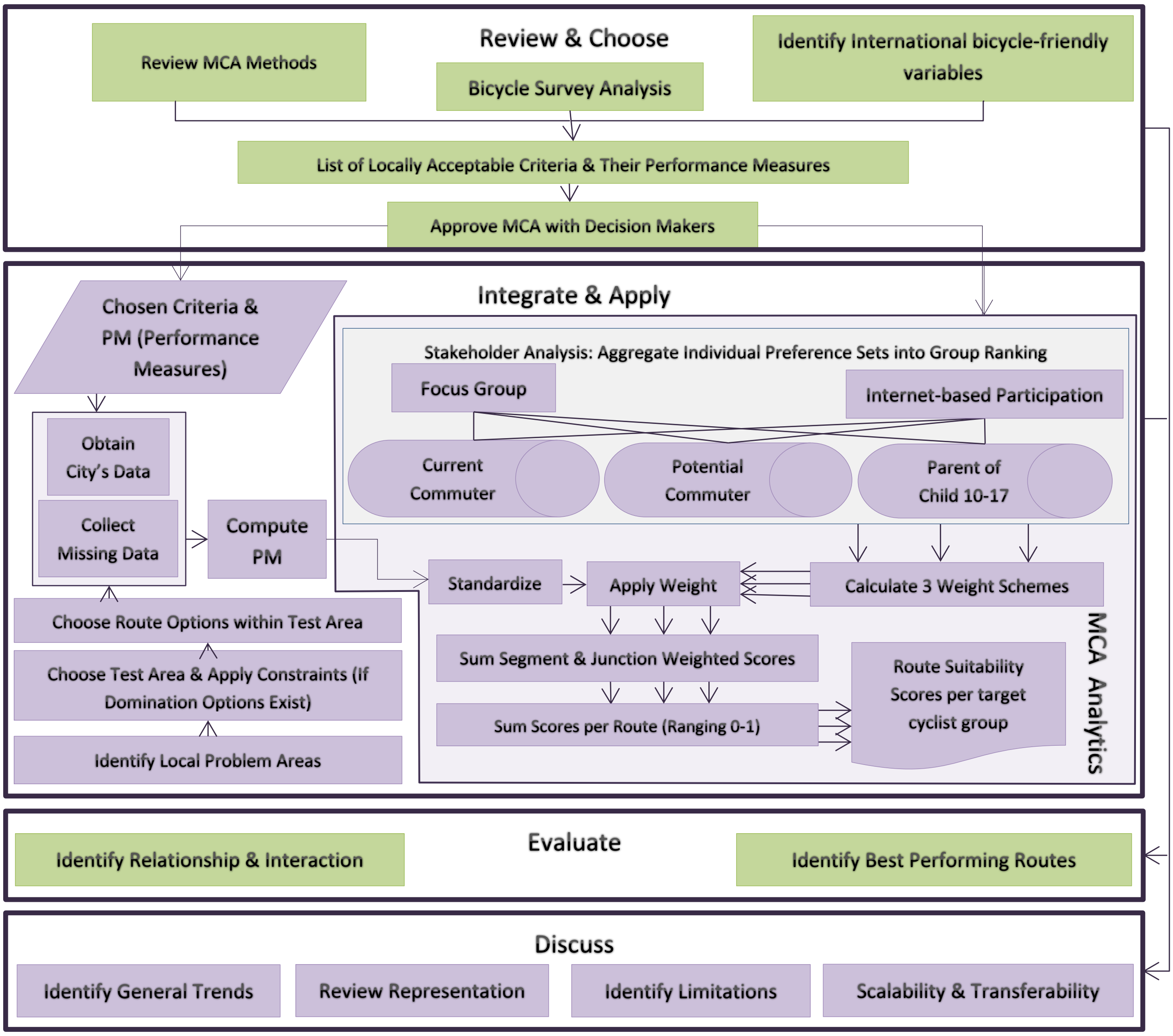


Figure 2: Specific Research Objectives & Their Associated Steps in the Research Design

2.3. Review & Choose

This section presents the table of chosen criteria and describes how and why they were selected. The review of international literature revealed 49 criteria which could be relevant for Christchurch. This full list is in Appendix A, Part 2. While many seemed important, only those criteria which were proven to have a significant effect in past studies could be included. Some of the criteria found were directly asked for in local policy and technical reports, so these too were considered. In the end, the 49 criteria were narrowed down to 17. These 17 were then grouped by their similarities. Some such as noise and pollution could have been placed in multiple categories, but were eventually placed in the category where they had the most mentions in the literature. Returning to the last example, noise and pollution are debated for the severity of their health impacts, but the displeasure of cycling behind noisy and heavy-polluting vehicles is hardly debated, hence it was categorized under attraction and not safety. The final list of 7 main criteria and 17 sub-criteria was shown to Christchurch's Cycleway Program Manager, the lead Senior Traffic Engineer, the City Council Transport Network Planner who was in charge of the 2014 bicycle survey, as well as a leading transport engineer from the University of Canterbury. Furthermore, performance measures were discussed. These representatives approved the criteria to be included in this bicycle route assessment procedure.

Table 2 Chosen Criteria Hierarchy & Performance Measures

Main Criteria	Sub-Criteria (Segment or Junction data for Test Area)	Performance Measure Computed As
Comfort	Non-slip Surface (Segment surface material chip size)	Chip size as proxy for Macrotexture skid resistance (not accounting for weather conditions or seasonal microtexture variations after Surface Friction Coefficient Equilibrium has been reached) Improvement Advice: **If available use SCRIM measurements, as advised by Transit New Zealand, for most reliable results.**
	Roughness (avg per road Segment)	Link NAASRA Average = ((Sum (Tilt Counts / 20 meters)) / Number of NAASRA measures per Link)
Road Capacity	Effective Width (Segment Width relative to 24-hour 4 day average ADT)	Wv= Effective Width as a Function of Traffic Volume Wt= Total Pavement Width of Shoulder and Outside Lane Wv= Wt if ADT > 4000 veh/day Wv= Wt (2-.00025 x ADT) if ADT ≤ 4000 veh/day and if the carriageway is unstriped and undivided Adopted From: (Landis, Vattikuti, & Brannick, 1997) Improvement Advice: **Repeat Landis and colleagues 1997 BLOS study in the local city to further validate volume function, which is based on a linear regression model representative of North American collector and arterial roadways.**
	Traffic Composition (Segment % non-light vehicles)	% medium and heavy vehicles (categorized by weight and specified by RAMM definitions)
Junction Safety	Visibility (junction avg meters to potential obstruction)	Average Visibility = ((Sum of Distances to surrounding properties) / number of surrounding properties)
	Speed & Volume (junction speed as km/h & volume as 24-hour 4 day average ADT)	Speed*volume Improvement Advice: **Repeat Landis' 2003 Through Movement Intersection BLOS study, and via regression modelling identify local New Zealand coefficients for total width, crossing distance, number through lanes, and volume of directional traffic.**
	Facility Capability (junction avg reserve width)	Average Reserve Width = (Sum of roadway reserve widths) / number of roads at junction
Directness & Efficiency	Detour Factor (DF segment * DF Route)	Segment Detour Score = (Link Length / Optimal Link Length) * (Route Length / Optimal Route Length)
	Right-hand Turns (junction turn count)	Sum turn counts for both directions
	Delay (seconds avg per junction)	Average Delay = ((Sum of the Junction's Delays Along the Route Directions) / number of directional delays)
Connectivity & Transit Cohesion	Connectivity (segment length)	Measured from cyclable cross-street to cyclable cross-street (un-named residential and commercial cul-de-sacs)
	Bus Stops (# within 100m network distance of segment	Count of bus stops within 100meters of road segment

	ends)	
Attractiveness	Art/Parks/Public Areas (segment % frontage)	% Public Frontage = meters of public frontage along route link / total meters of route link
	Noise & Pollution (Junction estimated noise as dBA Leq/day & volume of vehicles which expose cyclists to more PM10 estimated as vehicles/day)	Intensity of Noise & Pollution Emitting Vehicles = (24 hour dBA Leq within 10 m) * ((24 hour ADT) * (Percent Heavy Emitting Vehicles)) Adopted from: the (Acoustic Engineering Services, 2009) report completed for Christchurch City Council **Improvement Advice: Have pollution and noise monitors placed at intersections of interest, so a more precise performance measure can be made.**
	Street Lighting	Link Lighting = Number of Street Lights Along Link / ((Total Carriageway Width) * (Route Link Length))
Trip Generators & Attractors	Population Adjacent to Segment	Population Adjacent to Link = (number dwellings adjacent to link)*(average household size) / (Route Link Length) Adopted from: (Christchurch City Council, 2014a) who reported an average 2013 household size of 2.5 people per dwelling, and the bicycle Latent Demand Score (Landis et al., 1997).
	Destinations Adjacent to Segment	Destination Adjacent to Link = number of non-residential destinations with direct access to link / (Route Link Length) Adopted from: the bicycle Latent Demand Score (Landis et al., 1997) which uses attractions such as employments, shopping centres, parks, and schools.

To assess a bicycle route, its main components must be identified and analysed. As stated previously, the Dutch engineering group CROW (2007) identified the five broad categories of bicycle-friendly infrastructure as comfort, safety, cohesion, directness, and attraction. While these categories are generally agreed to influence cyclist behaviour and perceptions, there are many sub-criteria within these categories. Local situations and different transportation planning paradigms (demand or supply) tend to dictate which criteria are included within the assessments. Thus, there is little consistency internationally. At the beginning of this research, a list of potential bicycle-friendly criteria was reviewed. This was done by searching international journals and peer-reviewed articles, then comparing these with Christchurch transportation goals, and an analysis of a July 2014 Christchurch bicycle survey. The results of this survey will be further discussed at the beginning of the next chapter. A full list of the 49 sub-criteria considered, as well as their reasons for being included or not, can be found in the Appendix A, Part 2. At the end of this process, 17 sub-criteria were chosen, hierarchically categorized, and assigned performance measures. These sub-criteria and their specific performance measures were approved by the Christchurch representatives. Some of the performance measures had data readily available at the road segment and junction scale, though others (non-slip surface, noise, pollution, and demand) did not and their performance measures had to be approximated under assumptions. Below is the justification for these assumptions and the table displaying how the performance measures were computed for each criterion.

Non-slip surfaces were included as a comfort sub-criterion in this bicycle route assessment and this study refers to the text *Chipsealing in New Zealand* from Transit New Zealand, Road Controlling Authorities, and Roading New Zealand (2005) for the performance measure of chip size. New Zealand had a skid resistance policy developed in 1998, and which is discussed in Austroads' guidelines, but it is up to Road

Controlling Authorities to introduce this into local planning and asset management. Skid resistance and texture depth is crucial for road safety and raising the road surface skid resistance decreases the rate of wet skidding crashes (Transit New Zealand, Road Controlling Authorities, and Roading New Zealand, 2005). There are many factors which influence road surface macro and microtexture for skid resistance. A freshly laid road surface's macro and microtexture skid resistance levels drop for a few months, or years, before they reach equilibrium. From this point on, macrotexture is the largest determinant for how long a chipseal can remain comfortable and skid resistant, but chip size can be used as a simple proxy for macrotexture when there is lack of time and equipment resources. The test application shown in this thesis uses the macrotexture proxy. However, if ESC (Equilibrium SCRIM Coefficient) data is available from a SCRIM (Sideway-force Coefficient Routine Investigation Machine), then this should be used as the criteria's data input as it is more reliable. SCRIM data is the New Zealand Chipsealing standard because it accounts for seasonal fluctuations with microtexture of the chips before computing the ESC (Transit New Zealand et al., 2005). This study used chip size as a macrotexture proxy, assuming the roads in the study area were old enough to already reach their skid resistance equilibrium.

Unlike purely quantitative and widely-used supply sub-criteria, attraction sub-criteria were harder to justify as they were not explicitly stated in best practice guides, but this author felt it important to include noise and pollution in the assessment procedure due to the potential societal benefits and mitigated exposure to vulnerable sub-populations. Though a cyclist's individual health benefits generally outweigh the health risks (De Hartog, Boogaard, Nijland, & Hoek, 2010), the impacts of noise and pollution on vulnerable populations can still be avoided by choosing a cycle route on less traffic intensive streets (Hatzopoulou et al., 2013). Even individuals who are otherwise healthy still have increased risk with young or old age. While studying morbidity symptoms in otherwise healthy children, Cross, Heath, Ferguson, Gray, and Szymlek-Gay (2009) found an approximate 50% of South Island, New Zealand two year olds' illnesses were categorized as respiratory infections. And those aged 45-85 have respective increases in CHD (Coronary Heart Disease) mortality by an associated 4-6% due to elevations in traffic related noise and black carbon fine particulates, and 22% increased CHD mortality associated with day to day exposure to the highest traffic noise decile (Gan, Davies, Koehoorn, and Brauer, 2012). Roadways with diesel and other heavy vehicles are key bicycle route indicators as the proximity of these vehicles are associated with a 15% increased black carbon exposure to cyclists (Hatzopoulou et al., 2013). Despite improved vehicle emission policies, during the winter of 2014, Christchurch's night-time PM_{10} levels surpassed the recommended maximum of 50 $\mu g\ m^{-3}$ a recorded 23 times (Environment Canterbury, 2015). In areas without heavy industry or construction activities, the main source of these pollutants is the road network. Diesel's PM_{10} emissions are considered the most harmful for human health (Land Transport New Zealand, 2007). All road users are also exposed to these while travelling in dense traffic and car passengers arguably more so than cyclists. In New Zealand, there is yearly an approximate 399 cases of premature mortality associated with PM_{10} particulates emitted from vehicles (Kingham, Pearce, and Zawar-Reza, 2007). Thus if a city would like to provide safer, lower exposure travel options for these sub-populations potentially at risk, then cycleways could be provided on roads with lower chances of noise and pollution. If there were more noise and pollution monitoring stations in Christchurch, this study would have utilized their data. However, there are only a few such stations for the whole Canterbury region. Instead, this study uses a proxy for intensity of noise & pollution emitting vehicles, assuming the dBA Leq and the number of heavy emitting vehicles has a compounding effect on the cyclists within 10 meters of the traffic at the route junctions. Citing the official Christchurch report done by Acoustic Engineering Services (2009), this study secondly assumes noise and pollution are directly relatable to volume and composition of traffic.

Unlike noise and pollution, demand criteria such as trip attractors and trip generators are commonly accepted for their inclusion in transportation planning and facility design, however there are still difficulties when the data has large changes in its spatial and temporal scales. In New Zealand it is generally assumed bicycle demand is the same as vehicular demand which favours the combination of arterials with high flow capacity and a proximity to trip generators/attractors (Land Transport Safety Authority, 2004). This paradigm does not account for modal choice and its resulting trip generation matrix is a generalization of space and movement which may not work as well for bicycles as it does for vehicles (e.g. weather conditions affect choice to cycle and time of day affects cyclist route choice). Perhaps these behaviour variances are the reasons Christchurch's current multimodal CAST (Christchurch Assignment and Simulation Traffic) model does not include cycling estimates. Further difficulties arise when stretching estimates over large temporal scales. Since the CAST network model uses TAZ estimates from the base year of 2006 (Wright and Roberts, 2011), and because these are zone aggregates which are less informative on the scale of road segments and junctions where cycling microenvironments become important, this study does not include the CAST model estimates for its route scoring.

Furthermore, if demand is to be integrated with supply then they have to be on an operational level which is reflexive. As stated by Rybarczyk & Wu (2010), "Bicycle demand models typically utilize aggregate data to determine flows from one area to another. As a result, this approach does not indicate site specific facility improvements or represent actual increase in usage if a bicycle facility is implemented". To avoid the traditional demand model's "averaging effect" across whole zones (which would happen to route demand criteria scores on this assessment's segment scale), each of the route's roadway segments have been assigned only the population and non-residential destination counts which are adjacent to them and have direct property access. The population values were de-aggregated onto the property level, then dwelling counts and Christchurch's average household size of 2013 (2.5 people per dwelling as stated by Christchurch City Council (2014)) were combined to estimate the people with direct access to each road segment. This thesis acknowledges there is inaccuracy when applying dwelling size estimates, yet since they are based on the 2013 city-wide average and the 2013 cadastral dwelling data, this study assumes these are reasonable for comparing road segments against each other. Additionally, if the results are later applied to the segments of the whole Christchurch network, then the 2013 data can be used to enhance the CAST model zone estimates.

2.4. Integrate & Apply

2.4.1. Choosing an Area and Route Options to Test the Procedure

After discussion with the city representatives, a number of problem areas in the city-wide cycle network were identified. However, many of the problem areas already have bicycle projects underway. Long-term construction projects, intensive industry areas, and unstable slopes were discussed as potential hazards to be avoided. For a city-wide assessment, these strict dominance areas could be included as constraint criteria to be removed prior to assessment. . For this thesis a problem area which did not have any current construction projects was desired by the decision makers. The Cycleway Program Manager and the lead Senior Traffic Engineer suggested this research test a section of the Norwest Arc. The Norwest Arc is an 8 km planned bicycle route which their designers had previously identified. From this planned route a test area and route options were chosen. For this test area, no hazards were present at the time of fieldwork and did not have to be included into the route assessment procedure. The map below displays the two routes chosen to test the assessment procedure. Route Option 1 is the city's initial route choice (the middle section of the Norwest Arc) and is 1.56 km long. Route Option 2 was chosen for its diversity of population, non-residential destinations, speeds, and traffic volumes. At 1.92 km long, Option 2 has a higher detour factor. It was chosen to specifically to gauge the performance of long routes with the aggregate weights identified by potential commuter cyclists and parents of 10-17 year old children. Commuter cyclists often highly value directness and fewer delays at light controlled intersections, but it is unknown how other groups gauge directness. With the diversity of these route characteristics, the conflicts between different ideal bicycle-friendly infrastructures can be analysed.

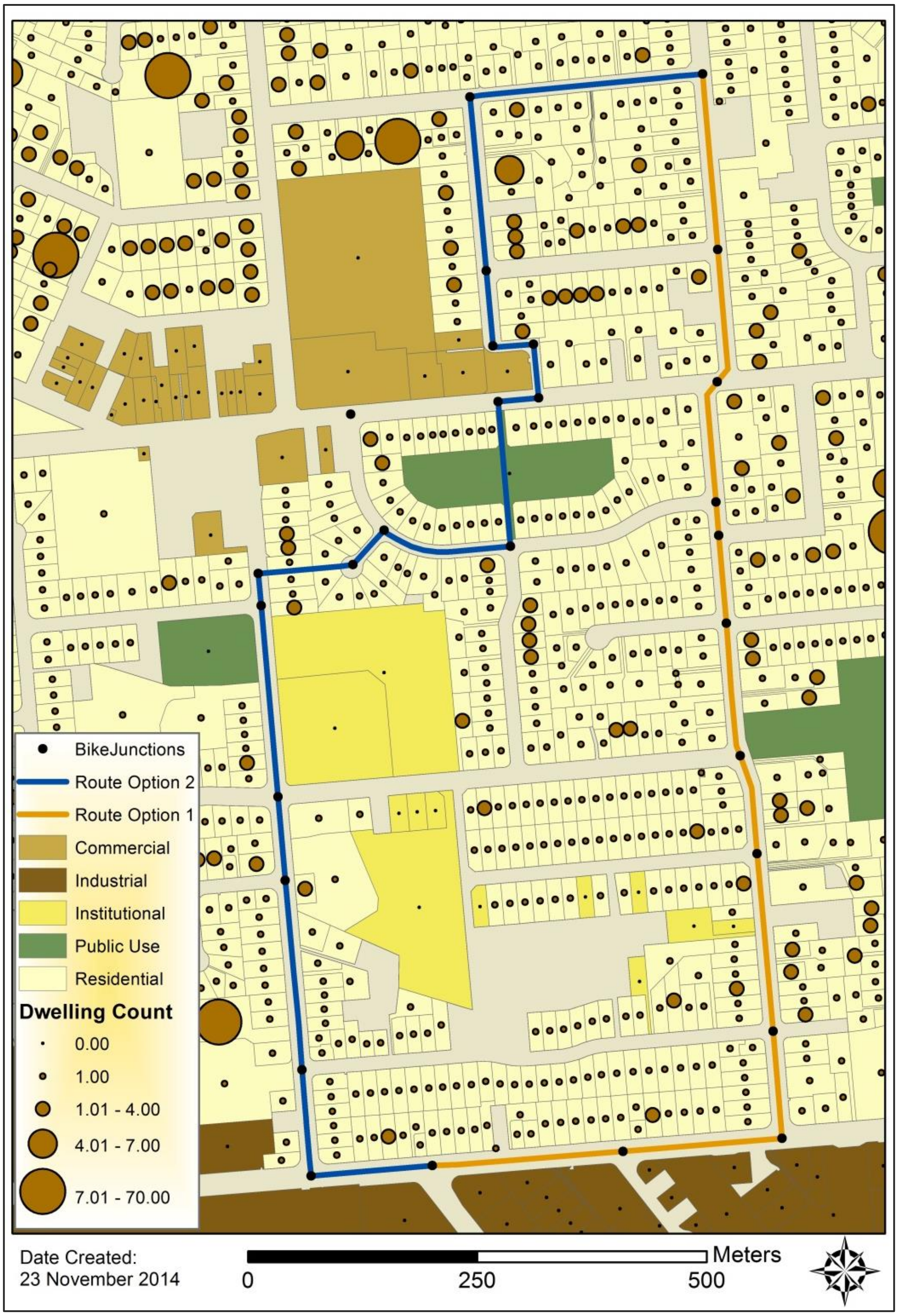


Figure 3: Test Area Chosen for this Thesis

2.4.2. Data Collection

Once the criteria and test area were approved, contacts were given via the above listed city representatives for the necessary datasets (shown in the table below). Some data was not available and was unable to be measured during fieldwork due to lack of equipment (mainly the SCRIM which measures surface friction coefficient, and noise and pollution monitoring stations, updated and de-aggregated CAST demand estimates). These were given proxies from data which was available. Other datasets (cadastral parcels and roads miscellaneous) were available, but were missing values for some road segments and junctions. For these, measurements and counts were manually completed during fieldwork. Below are the datasets and how they were obtained. The main contacts were associated with the CCC (Christchurch City Council), or the UC (University of Canterbury).

Table 3 Datasets Used in Test Area

Dataset	Pertinent Information	Obtained Through
July 2014 Bicycle Survey	Cycling Perceptions & Frequencies of over 1500 Christchurch residents	Karyn Teather (CCC Asset & Network Planning & UC Alumni)
Road Asset and Maintenance Management (RAMM)	Chip size, NAASRA Roughness, ADT, Traffic Composition, Reserve Width & Carriageway Width	Binaya Sharma (CCC Asset & Network Planning, City Infrastructure Division) & Updated via Counts Website http://www.ccc.govt.nz/cityleisure/projectstoimprovechristchurch/transport/trafficcount/index.aspx
Cadastral Parcels	Land use, Frontage, Dwelling Units, Commercial Tennant	Josh Neville (UC MSc Student) & Updated via Fieldwork
Road Centerlines	Block Length & Road Name	Aimee Martin (UC Alumni)
Roads Miscellaneous	Speeds, Facility Photos, Right-hand Turn Counts, Directional Delay	Manually recorded during Fieldwork, samples of Directional Delay were timed during 8-9 am peak morning traffic for 20 minute intervals at each junction which would require a right turn
Bus	Bus Stops, Routes, & Shelters	Shannon Boorer (Environment Canterbury)

Once the necessary data was collected, the performance measures were computed for their respective road segments and junctions in ArcGIS attribute tables. The raw data shows there are variations present in the microenvironments of segments and junctions. For instance, NAASRA roughness is different at each meter along the route, and in some places is much worse than others. Despite these variations which exist, the performance measures are generalised (in this study) at the segment and junction level because doing so creates a simplified computation which can be assessed in detail on the route level, but which can also be easily scaled up to the city-wide network. And this will be easy to manage at municipal transport offices.

2.4.3. MCA Analytics

2.4.4. Performance Measurements to Standardized Criteria Performance Scores

Performance measurements for each road segment and junction must be standardised onto a common, unitless scale before they can be compared with each other. As demonstrated by Geneletti (2010) and others, this study will use linear maximum standardization prior to the aggregation of scores for each link and node. It is favourable among participatory suitability studies because it does not cause undue exaggeration between small measurement differences which may be due to measurement or estimation error and which also may be of only minor importance to the cyclist even when considering their microenvironment. This criteria standardization will result with criterion scores from 0-1, as is shown below.

$$\text{Standardized Cost Sub} - \text{criterion Performance Score} \ = \ 1 - \left(\frac{\text{actual score}}{\text{maximum score}}\right)$$

$$\text{Standardized Benefit Sub} - \text{criterion Performance Score} \ = \ \left(\frac{\text{actual score}}{\text{maximum score}}\right)$$

Value statements are inherent to each sub-criterion's performance measure. They indicate whether a high measure is beneficial or costly (detrimental) to the overall bicycle-friendliness of the road segment or junction. A cost sub-criterion indicates high performance measurements are negative to the cycling experience. Likewise, benefit sub-criterion indicate high performance measurements are positive. Applying the above equations categorize cost and benefit sub-criteria, then transform their scores so they are comparable to each other. Once this is done, then all the sub-criteria scores along the routes' segments and junctions can be given weights. Three sets of weight schemes were generated from the aggregated preference sets obtained during Stakeholder Analysis. How and why these weights schemes were generated is detailed in the next section.

2.4.5. Stakeholder Analysis: Compromising Between Cardinal Precision & Ordinal Simplicity

For this thesis participatory ranking, Direct Simple Ordinal Evaluation was chosen to produce the weighting schemes. This section first discusses why this method of ranking was chosen (instead of value functions which are common in transport planning and instead of pairwise comparison which is encouraged in MCA), then it goes on to describe how stakeholder analysis of 66 individuals (n=66) was incorporated to produce aggregated criteria weight schemes per target cyclist population group.

This study uses cardinal (quantitative) data and thus is justified to use value functions, and other precise quantified weighting methods. However, there are benefits to purely ordinal (qualitative) methods as they leave room for small changes in a criterion's specified weight while still maintaining the criterion's overall importance relative to the other criteria. Value functions are precisely defined and do not leave room for probabilistic uncertainty. This distinction is important if the same weight will be applied multiple times and in a variety of problem situations, as a city would be doing if their planning office were to incorporate an MCA into their program and compare multiple sets of cycling route options over several months or years. Since value functions are especially prone to error when the scale or situation changes (Pomerol & Barba-Romero, 2000), using their results for many projects is likely to add false precision to the decision being made. As Pomerol and Barba-Romero discuss in their book, purely cardinal evaluations of alternatives are highly sensitive to presentation, to differing criteria being presented, and to the order in which they are being presented. Because of this, the assigning of a criterion's precise utility is often seen as arbitrary. Furthermore, the issue of scale poses a problem for cycle route decision problem methodology as a city will have a great range of route lengths, as well as trip lengths. And as a bicycle friendly route would have a large number of potential criteria, and because it needs to satisfy a large number of stakeholders, fuzzy uncertainty is introduced, further justifying ordinal (qualitative and flexible) ranking over cardinal (quantitative and precise) utility.

Direct Simple Ordinal Evaluation is thought to be more robust because of its flexible nature. Its simplicity also makes it competitive with pairwise comparison, a method which is quality controlled and ensures consistency, but also requires a great number of questions to be processed by each stakeholder. Direct Simple Ordinal Evaluation is less time intensive and the information obtained remains reliable if the questions are fairly easy to answer. This was deemed an important advantage since the many stakeholders participating were non-experts and had limited time they were willing to spend.

To use ranking, this study assumes people have, at least partially, preconceived perceptions of cycling and personal preferences for criteria which can be represented in individual preference sets. This study also assumes the preference sets can be aggregated into stakeholder groups. Due to the city's goals of increasing cycling's modal share, this thesis has classified stakeholders into three target cyclist populations: current cycle commuters, potential cycle commuters, and parents with children aged 10-17.

For each of these three target cyclist groups, there were two rounds of stakeholder analysis. The first round invited respondents (from the July 2014 Christchurch bicycle survey who stated they were members of these target populations) to participate in six focus groups. These focus groups: 1) helped determine if there were any essential criteria which should be added to the bicycle route assessment; 2) identified current infrastructure problem areas and faulty designs; and 3) gave the individual's personal preference set for the criteria ranking. The focus groups also shed light on behaviour and perception drivers which are outside of the control of bicycle facility planners, and which may help better predict a realistic vision of a potential route's usage. The full results of the focus groups can be found in Appendix C, and a summary is given in the next chapter. Due to low turn-out for the in-person focus groups, the second round of stakeholder analysis was internet-based and aimed to broaden the diversity and sample size of stakeholders, hopefully to also include those participants who do not currently cycle, thereby increasing the likelihood of the stated preferences being representative to the wider Christchurch population. This second round of stakeholder analysis also extracted personal preference set rankings and the time valuation data necessary to the later MCA process. Together, the two rounds of stakeholder analysis gave 66 individual preference set rankings which could then be aggregated into the group weight schemes. Furthermore, the rankings were completed individually (even for the focus group participants) and did not suffer from the problems commonly associated with group-based analysis as discussed by Geneletti (2010). Common problems include under-representation of less assertive personalities and opinions and individual answers can be swayed or influenced by the comments given by other participants. Hence, group-based analysis is to be avoided if the MCA requires participants to state their personal preferences.

This thesis accommodated individual stakeholder's degrees of indifference by asking them to tell how sure of each ranking they were. The stakeholders were allowed to state to what percentage they were "sure" about the rankings they provided, with an answer of 0% indicating the criteria to be ranked seemed equally important. To minimize presentation bias (due to the order in which the criteria were presented), the ranking answers were presented in random order. These results of these individual preference set rankings were then aggregated, as detailed in the next section.

2.4.6. From Individual Stakeholder Preference Sets to Aggregated Group Ranks

Initial analysis of the stakeholder results had shown there was heterogeneity within the three target cyclist groups. This indicates the situation could have fuzzy uncertainty and the aggregation of the group results must be taken with care.

The ranks were aggregated from the n=66 stakeholder preference sets. As discussed by Mendoza and Martins (2006), of the three methods for heterogeneous group opinions (fuzzy situations) there are three options. Wanting to avoid the extreme pessimistic and extreme optimistic transformations, the compromising midpoint value was chosen for this thesis. It could have been either the mean or median, but with results showing a skewed criteria distributions, this researcher erred on the side of caution and used the median. Median criteria ranking sets of the three target cyclist group were then transformed into weights with the following:

$$W_i = \frac{R_i}{\sum R_i}$$

Where:

W_i weight assigned to the criterion i

R_i Aggregated group rank to the criteria i

Once the weights are aggregated for each target cyclist group they can be multiplied by their respective standardized criteria scores. Then the weighted summation equation (as shown below) can be used to combine the scores into a single route suitability score (Geneletti, 2010; S. Hajkowicz & Higgins, 2008; Pomerol & Barba-Romero, 2000). Shown below is an adapted version of this allowing for the same sub-criteria to appear multiple times within the route (i.e. an individual visibility score for each junction along the route) without averaging. This is important as any route options must be addressed not only by its total suitability score, but by the detailed performance of the road junctions and segments which form it. A bicycle route assessment which only gives one final score is of very little use to designers and engineers. However, this way allows each segment and junction to maintain its broken down scores before being included into the actual route sum. This actual route sum is then divided by the total possible route sum.

$$S = \frac{actual\ route\ sum \quad \sum_{i=1}^{n} W_i X_i}{total\ possible\ route\ sum \quad \sum_{i=1}^{n} W_i\, X_i} \qquad (i = 1, 2 \ldots n)$$

Where:

$$\sum_{i=1}^{n} W_i = 1 \qquad\qquad 0 < W_i \leq 1$$

S total route suitability score

n number of criteria

W_i weight assigned to the criterion i

X_i normalized score of criterion i

2.4.7. Sensitivity Analysis

A sensitivity analysis (via changing criteria weights) was used to verify the strength of the assessment's most suitable route option. Generally, if the suitability scores remain relatively unchanged even after alterations, then this signifies a robust answer of which route option is "best", or most suitable in terms of the bicycle-friendly criteria and weights scoring it. If the overall route suitability changes, then the weights at which this change occurred at is called a reversal point. If the reversal point occurs close to the original (stakeholder aggregated) weight value, then the total suitability scores are not stable (Geneletti, 2010). Sensitivity analysis accounts for errors and inaccuracies, as well as supporting the bicycle route designers and planners through a process which typically faces public opposition (Geneletti, 2010).

For this study, the weights were changed in four ways. One, the weights were distributed equally across all sub-criteria as if they all held equal importance. Second, the weights were changed with the stakeholder identified schemes. The averages of how these weights differed from the equal weights were then plotted. As expected, there was a reversal point after the weights were significantly altered. This indicates the route which is chosen would have to have improvement at its worst scoring junctions and segments prior to becoming significantly more suitable than the other route option.

3. RESULTS

The last chapter detailed the theories and techniques of MCA for bicycle-friendly infrastructure, and then described how and why the test area was chosen. This chapter presents the results of the bicycle survey, the stakeholder feedback summary, the stakeholder group criteria rankings and their corresponding weights, and displays how these can be used for detailed junction and segment analysis of each route a city would be considering.

Figure 4 Survey Demographics

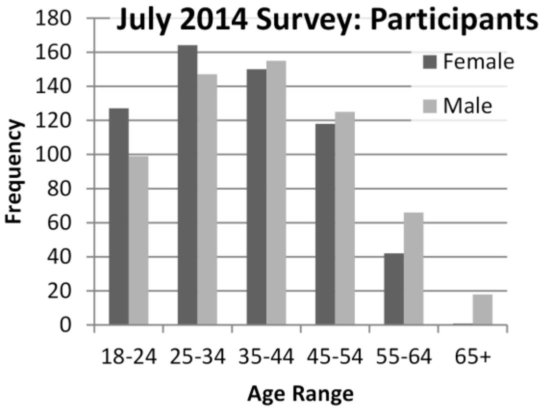
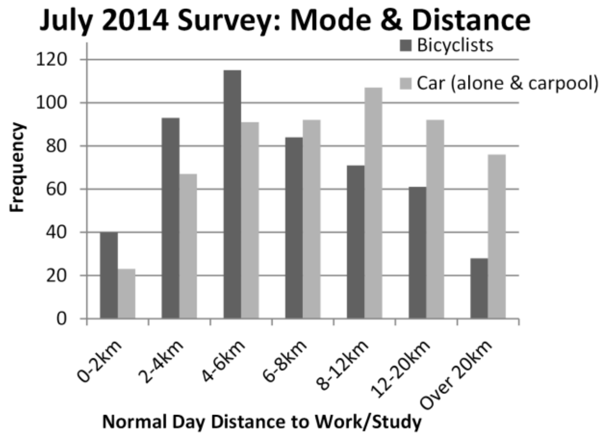


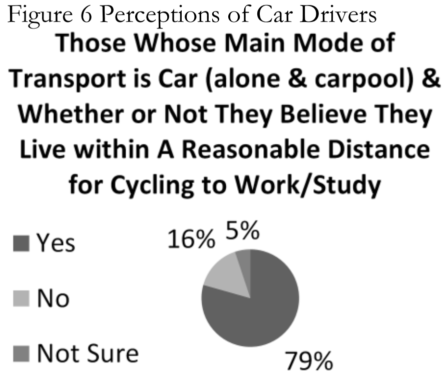
Figure 5 Survey Mode & Distances



3.1. July 2014 Christchurch Bicycle Survey

In July 2014, a survey was conducted by Karyn McClure and her colleagues at the University of Canterbury who subsequently allowed the use of their data for this research to assess how the identified target cyclist groups may be accommodated. The survey used both an online platform (advertised through social media) and in-person survey sheets. It is under representative of non-cyclists (those who do not currently cycle for utility or recreation), and those parents with children between the ages of 10-17, and novice cyclists. There were 1517 respondents, but only 1218 cases were left after removal of unfinished surveys and repeat cases.

Figure 6 Perceptions of Car Drivers



This research identified three target groups: current (cycling) commuters, potential (cycling) commuters, and parents of 10-17 aged children. Thus, survey respondents were analyzed for their main mode of transport to and from work/study, for their frequency of cycling, and whether or not they cycle recreationally.

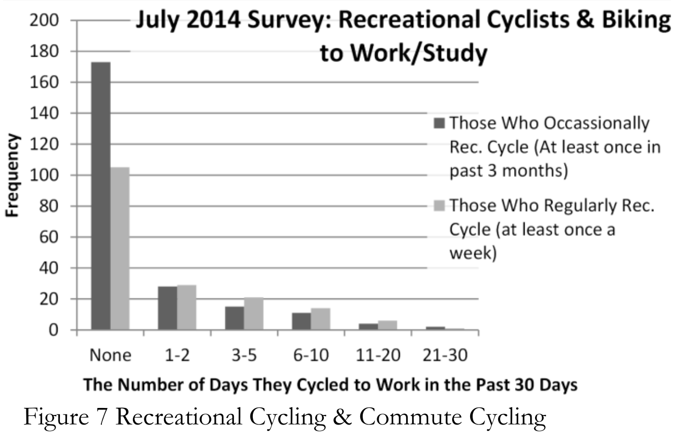


Figure 7 Recreational Cycling & Commute Cycling

The graphs at the side display how most recreational cyclists do not cycle to work, even when the majority of car drivers (79%) believe they live within a reasonable cycling distance. Those who do cycle are generally travelling shorter distances than those who go by car. These cycling distances align with the 4.8km average cycling commute as defined by the Christchurch City Council (2012). Also evidenced in this survey is the low ratio of the population who actually cycles, even though they do state to have at least considered cycling to work/study (59% of survey respondents who mainly drive). This phenomen could be attributed to the general convenience of driving, however a large portion of these drivers also state they have concerns so they never or rarely ride a bike on the streets of their neighborhood. It also indicates that successfully targeting these interested but concerned individuals may require broader policies and extra design measures to increase the bicyle-friendliness of these neighborhood collector roads. They are likely the largest portion of the adult population who does not currently commute by bicycle, but who could be enticed to in the future. However, these potential commuters may not be sufficiently reassured to use the routes of official cycleways until the general city-wide cycling conditions are improved.

Figure 9 Car Drivers Perceptions of Cycling

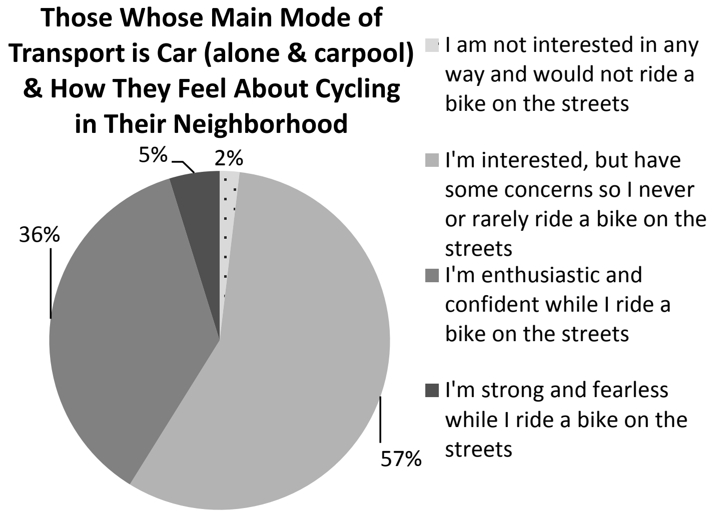
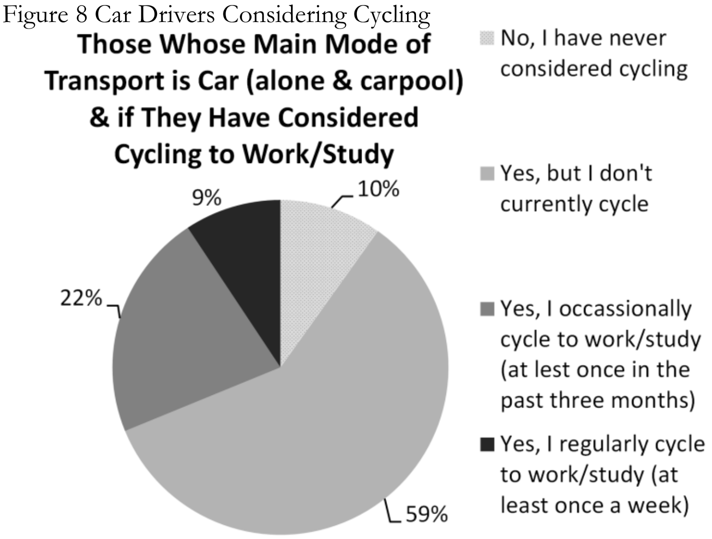


Figure 8 Car Drivers Considering Cycling



There seems to be a stark difference in feelings between those who regularly cycle as their main mode and those who do not, which suggests perceptions change with experience. While 57% of those who commute to work/study mainly via car have concerns, only 3% of actual commuter cyclists would categorize themselves in this fashion. Most respondents who state the bicycle to be their main mode of transportation to work/study are enthusiastic and confident (and 17% even claim to be strong and fearless) on their neighborhood streets. For these individuals who are likely used to cycling in less bicycle-friendly conditions the level of cycleway design probably would not need to be as extensive to attract them into using the facilities. Due to these apparent differences bicycle facility planners and designers would benefit from knowing exactly which criteria of a bicycle-friendly route are enticing to these target cyclist group.

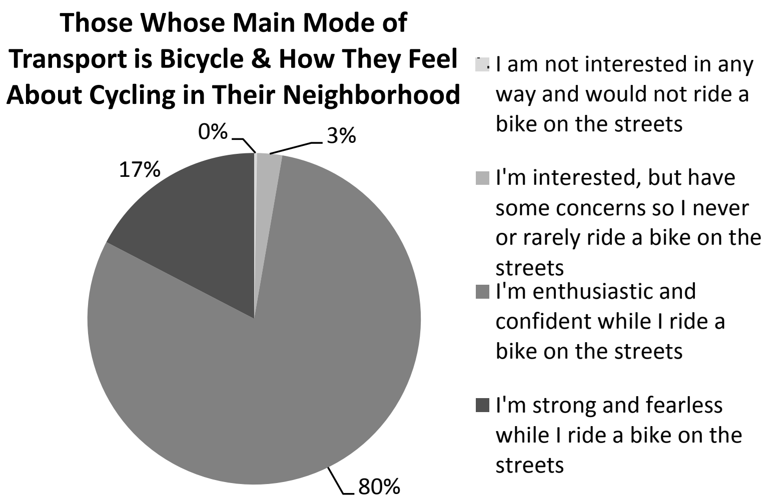


Figure 10 Perceptions of Regular Cyclists

As shown below, many factors were mentioned as things which would encourage the respondents themselves or their children to cycle more. While this shows a variety of factors which may increase Christchurch's modal share, the majority of respondents claimed improved cycleways would encourage them to cycle more. Separation from motor vehicles, improved cycle routes, more courteous vehicle drivers, and less traffic on the road were the most common factors mentioned. From here, this assessment procedure can elaborate upon what each of these groups constitutes as encouraging or good cycleway design. In the Parent's table below, 21% listed "other" and many of these comments were focused on safety or distance between their home and school.

Table 4 Factors Encouraging Commuters to Cycle

Survey Question: What would encourage you to cycle (or cycle more regularly) to work/study? (tick all those factors that apply)	% of each target group who mentioned this factor as something which would encourage them to cycle more:	
	Of 569 Commuter Cyclists (who cycle to work/study at least once a week)	Of 649 Potential Commuter Cyclists
Nothing would make me cycle to work	0.0%	3.7%
Improved cycle routes (e.g. painted cycle lanes)	73.5%	61.5%
Cycle routes with separation from motor vehicles (e.g. grass berms or raised kerbs)	80.0%	78.0%
Access to locker/shower facilities at work	33.6%	31.4%
Help with improving my cycle skills and confidence	4.2%	7.9%
Improved security for storing cycles at work	23.7%	22.5%
Less traffic on the roads	48.2%	42.1%
More courteous vehicle drivers	71.4%	60.9%
Harder to find or more expensive car parking	14.9%	8.6%
More traffic congestion making cycling a relatively quicker option	26.7%	16.3%
A large increase in fuel costs	21.1%	18.3%
Having the opportunity to cycle to work with other people	8.3%	8.3%
Discount prices to buy a bicycle	21.8%	10.6%
Having a usable bicycle of my own	5.4%	5.1%
Other	13.4%	22.8%

Table 5 Factors Encouraging Children to Cycle

Survey Question: If your children do not cycle to school, what would encourage them to cycle to school (or you to allow them to cycle to school)? (tick all those factors that apply)	% target group who mentioned this factor as something which would encourage them to cycle more: Of 213 Parents of Children Aged 10-17
Nothing would make me allow them to cycle to school	3.8%
Improved cycle routes	55.4%
Cycle routes with separation from motor vehicles	72.3%
Help with improving their cycling skills and confidence	27.2%
Less traffic on the roads	36.6%
More courteous vehicle drivers	54.5%
Having the opportunity to cycle to school with other people	20.7%
Discount to buy a bicycle	4.7%
Other	21.6%

3.2. Stakeholder Analysis

This section covers the comments made during the focus groups and the specific cycling problems they identified (the full list of comments is included in Appendix C). It goes on to give the criteria time values and the summary tables of the aggregated preference set rankings for each target cyclist group.

3.2.1. Public Perceived Difficulties with Cycling in Christchurch

Of the 200 people invited to the focus groups only 20 came to participate. The discussion identified difficulties for cycling in Christchurch and issuing some solutions which could address them. There were 156 comments recorded. These came from individuals and some were elaborated through group discussion. Here is a list of the comments which are more general and could apply to the network:

- "Bike route to school: Ideally any road should be safe for kids to ride to school. School/Home (trips) will be different routes for all children, and children like to have independence to go visit friends, etc. If there were more cyclists of all ages on the road I would be more comfortable with my children cycling."— *Kate Palmer , Comment 1*
- There is a general lack of awareness in regards to cyclists. Car drivers simply do not think cyclists will be on the road. —*Discussion, Comment 18*
- 100% of focus group members agreed they'd had problems with cars not giving way when they should.—*Discussion, Comment 17*
- "Cyclists have a dehumanized image. This can improve if cyclists are more openly friendly and remind the drivers they are people too through waving and other good behaviour. Interacting and communicating are important."—*Grace Ryan, Comment 27*
- (Personal) Perceptions of safety improve once people start cycling themselves. And people are better able to see the direct benefits. There's environmental value, it can be just as fast for time, and cyclists save money from not buying petrol. Also, cycling seems to be less of a stop and start trip than what is typically experienced in a car. Cycling is a more continuous travel experience and involves less idling, but non-cyclists do not know this. —*Discussion, Comment 30*
- There is an anti-cyclist sentiment. People tend to think, "all cyclists wear lycra", or "all cyclists run red lights".—*Discussion, Comment 35*
- "Right now there is no easy way for people to offer advice on which areas or designs need infrastructure improvement. Nor can people easily report when the cycle lanes are in poor condition and need maintenance. There should be an app for people to give constructive, location-specific maintenance and infrastructure advice."—*Glen Tregurtha, Comment 36*
- 100% of focus group agreed there was insufficient space on many streets. That there was not room for parked car doors, bikes, and trucks. That when car doors swing out, the cyclist has to veer to avoid it and endanger themselves with traffic. The focus group agreed the "door space" painted on the road helped protect them from this. —*Discussion, Comment 56*
- Changes to traffic controls (due to road works) forces drivers and cyclists to constantly re-assess where they should be in relation to one another, which regularly increases risk.—*Discussion, Comment 61*
- "Dangerous Roundabouts multi-lanes" (at Blenheim and Main South Rd, Riccarton Ave and Deans Ave)—*Glen Tregurtha, Comment 91*
- "Crossing Brougham to Gasson. Cars routinely track into the cycle lane at Brougham. Maybe a few rumble strips would remind them."—*Meg Chrishe, Comment 103*

- "(Ilam Road) Slow stack behind other cyclists. Can't overtake. Not wide enough. Some of the chicanes are unsafe to take at speeds above 30 km/h. Very bumpy. Not enough space to avoid hazards such as broken glass."—*Jason Motha, Comment 117*
- "Cycle lane outside Macpac narrows to only 30 cm…" (on Blenheim Rd near intersection with Mandeville St)—*Glen Tregurtha, Comment 119*
- There are junctions missing complete Advance Stop Boxes which could sorely use them and those junctions which do have them are often an incomplete design or poorly constructed.—*Discussion, Comment 126*
- "Intersection (at Riccarton Rd and Clyde Rd) is too congested at peak hours/cars block cycle lane when turning left off Clyde Rd…cars are using the cycling lane as a teeming lane, blocking it"—*Tim Hate, Comment 151*
- "Gap in cycle network (between Canterbury Park & Birmingham Dr), is very dangerous with lots of trucks."—*Shannon Boorer, Comment 156*

These and other comments were categorized, with the highest amount being categorised as driver behaviour, right-turn difficult/danger, and media/public perception/initiatives. Fourth and fifth most commented were mentions of through intersection difficulty/danger and unclear design. Below is a summary of what was mentioned in the cycling discussion. The full list of comments is in Appendix C.

Table 6 Focus Group Comment Summary

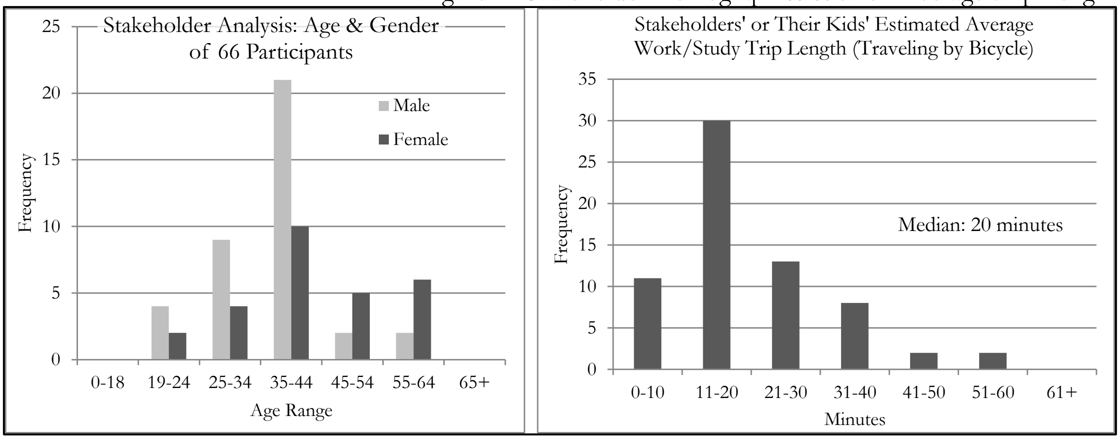
Comment Category	Comment Sub-category	# Times Mentioned in Focus Groups	%	%
Behavior	Cyclist Behavior	7	4.5	15.6
	Driver Behavior	18	11.5	
	Media/Public Perception/Initiatives	11	7.1	
	Pedestrian Behavior	2	1.3	
Connectivity	Lack of Options	4	2.6	2.6
Good Facilities	Cycle Lane Separation	5	3.2	5.8
	Intersections	5	3.2	
	Parked Cars	4	2.6	
Maintenance	Broken Glass	2	1.3	2.5
	Road Works	4	2.6	
Navigation	General Road Segment Difficulty/Danger	6	3.8	16.8
	Lane Change Difficulty	3	1.9	
	Left-turn Difficulty/Danger	3	1.9	
	Right-turn Difficulty/Danger	13	8.3	
	Roundabout Difficulty/Danger	6	3.8	
	Through Intersection Difficulty/Danger	10	6.4	
Obstruction/ Visibility	Parked Cars	7	4.5	4.5
Poor Facilities	Designed Cycleways around Car Parks/Bus Stops	3	1.9	14.8
	Disjoint Segment Cycle Lanes	2	1.3	
	Major Cycleways Too Narrow	4	2.6	
	No Cycle Facilities	8	5.1	
	Shared Cycle Lane/ Footpath	6	3.8	
	Transfer Between Segment Cycle Facilities & Junctions With No Facilities	4	2.6	
	Unclear Design	9	5.8	
Traffic Related	Bus Conflict	4	2.6	4.1

	Congestion Blocks Junction Cycle Lane	2	1.3	
	Road is too Busy	2	1.3	
	Truck Conflict	2	1.3	
Total		156	100.0	100.0

3.2.2. Criteria Time Values per Target Cyclist Group

Below is the first series of results from the web-based stakeholder participation, which included responses from 66 Christchurch residents. Of this group there were 18 potential commuters, 32 current commuters, and 16 parents of children aged 10-17. These were not large enough sample sizes to assume the results could be representative of Christchurch's whole population, but there was a roughly normal age and gender distribution. These were deemed adequate to test this route assessment procedure. Each stakeholder was asked to rank the 7 main criteria and then to value them against their or their child's average trip to work/school. The responses were handed in via email and through the website Esurv.org. This opportunity to participate was publicised by the newsletter of bicycling advocacy group Spokes, the social network of City Life Church, as well as the Facebook group of Christchurch Mountain Bikers. The box and whisker plots show the group rankings are fairly consistent with the time values. Since the time values are skewed, the median is being used as the central tendency. Refer to the trip length graph below for comparisons.

Figure 11 Stakeholder Demographics & Their Average Trip Length



Overall, potential cyclists had higher time values for each criterion than those who do regularly cycle. This was anticipated and the results support the findings of Börjesson and Eliasson (2012), who stated time values can change based on cycling frequency or experience. Unexpectedly, the results of the test assessment did not show a trend sufficient to say time value is correlated with trip distance, but this is likely due to the small sample sizes of these participating groups.

Main Criteria Importance Ranking
1 = Less Important & 7 = More Important

Criteria Time Values
(Min) Willing to Add to their Average Trip for the Criterion

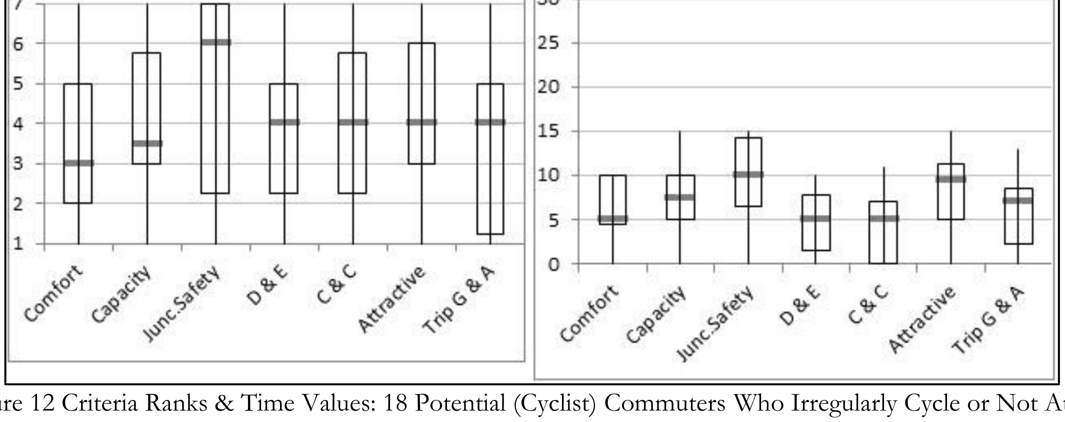


Figure 12 Criteria Ranks & Time Values: 18 Potential (Cyclist) Commuters Who Irregularly Cycle or Not At All

Main Criteria Importance Ranking
1 = Less Important & 7 = More Important

Time Values
(Min) Willing to Add to their Average Trip for the Criterion

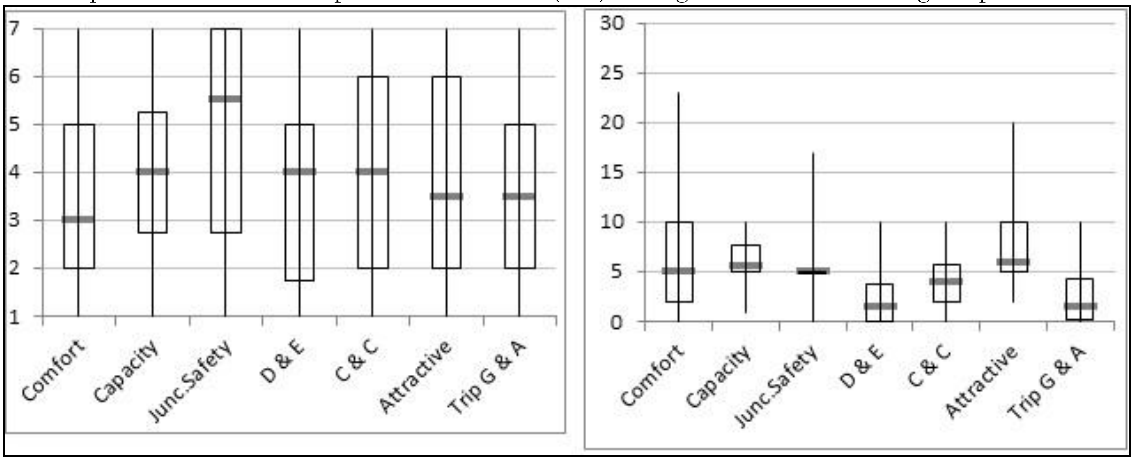


Figure 13 Criteria Ranks & Time Values: 32 Current (Cyclist) Commuters Who Cycle to Work/Study Regularly—at Least Once a Week

Main Criteria Importance Ranking
1 = Less Important & 7 = More Important

Time Values
(Min) Willing to Add to their Average Trip for the Criterion

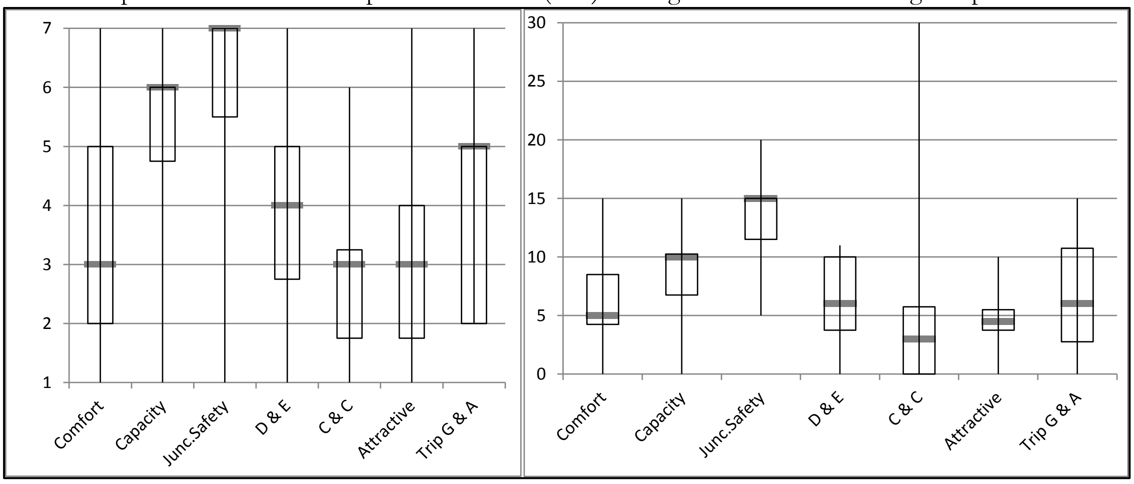


Figure 14 Criteria Ranks & Time Values: 16 Parents of 10-17 Aged Children

From these time value plots the commuter cyclists likely have the most accurate time estimates and most realistic criteria time valuations since they are the group with the most personal experience cycling to work/study. Of the three target groups, current (cyclist) commuters also appear to have the most homogeneity for their time values. Yet, it is the parent group which has the largest change in median time values for different criteria. This likely indicates these parents as a whole have strong preferences for junction safety and capacity. Whereas adults who are judging the criteria for their own trips seem to have higher degrees of personal variance and are more willing to sacrifice junction safety for attractiveness, comfort, and the convenience of routes near their trip generators and attractors.

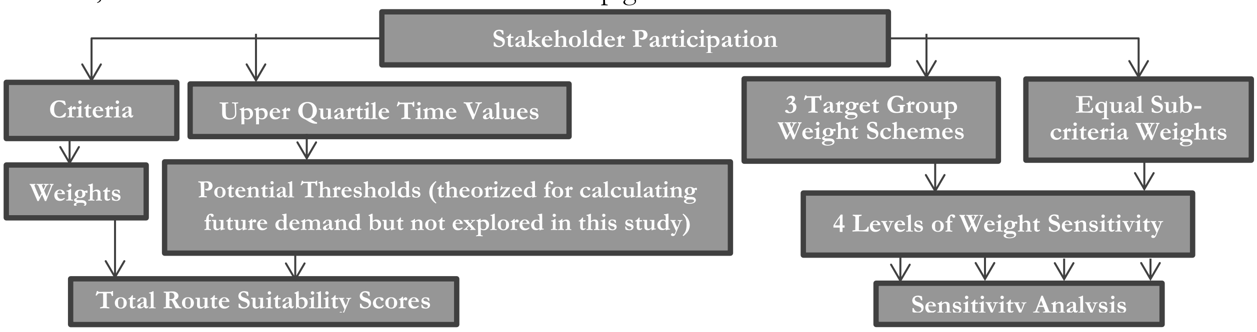


Figure 15 How Stakeholder Analysis Outputs Feed into the Route Assessment Procedure

3.2.3. Group Rankings and Aggregated Weights

Once the value-based criteria were chosen and organised into sub-criteria they were transformed into statements which were easy to understand for stakeholders who may have little to no experience in transport engineering. First, stakeholders were given a series of sub-criteria (grouped in their relative hierarchy sets of two and three) to rank on importance. Each question was asked in relation to the stakeholder's or their child's cycling to work/school. Second, the stakeholders were asked to rank the 7 main criteria (comfort, road capacity, junction safety, directness and efficiency, connectivity and transit cohesion, attractiveness, trip generators and attractors). As can be seen in the example form shown in the Appendix each main criterion was defined as being a general term for its underlying sub-criteria. Once the stakeholder rankings were complete the answers were aggregated into their respective target cyclist group.

Due to the skewness shown in the above criteria time values it was thought the rankings might also contain stakeholder answers which are more extreme than what is typical for these target cyclist populations. Thus, the median was used for the aggregation of the individual stakeholder preference set rankings. Below is the result of the rankings once they were aggregated and converted into three criteria weight schemes. These tables show the rounded weights but the procedure used the fractions. The non-rounded weights sum to the normalized "1" satisfying the major assumption of Weighted Summation.

Ranks to MCW (Main Criteria Weights)

Figure 17 MCW of 18 Potential Commuters

Main Criteria	Median Stakeholder Rank	SDSS Weight (Rank/Rank Sum)	Median Stakeholder Rank Uncertainty	Rank Sensitivity ((R.U./2)* weight)
Junc.Safety	6	0.211	0.200	0.0211
D & E	4	0.140	0.200	0.0140
C & C	4	0.140	0.200	0.0140
Attractive	4	0.140	0.200	0.0140
Trip G & A	4	0.140	0.200	0.0140
Capacity	3.5	0.123	0.200	0.0123
Comfort	3	0.105	0.200	0.0105
Sum	28.5	1.000		

Figure 16 MCW of 32 Current Commuters

Main Criteria	Median Stakeholder Rank	SDSS Weight (Rank/Rank Sum)	Median Stakeholder Rank Uncertainty	Rank Sensitivity ((R.U./2)* weight)
Junc.Safety	5.5	0.200	0.300	0.0300
D & E	4	0.145	0.300	0.0218
C & C	4	0.145	0.300	0.0218
Capacity	4	0.145	0.300	0.0218
Attractive	3.5	0.127	0.300	0.0191
Trip G & A	3.5	0.127	0.300	0.0191
Comfort	3	0.109	0.300	0.0164
Sum	27.5	1.000		

Figure 18 MCW of 16 Parents of 10-17 Aged Children

Main Criteria	Median Stakeholder Rank	SDSS Weight (Rank/Rank Sum)	Median Stakeholder Rank Uncertainty	Rank Sensitivity ((R.U./2)* weight)
Safety	7	0.226	0.350	0.0395
Capacity	6	0.194	0.350	0.0339
Trip G & A	5	0.161	0.350	0.0282
D & E	4	0.129	0.350	0.0226
Comfort	3	0.097	0.350	0.0169
Attractive	3	0.097	0.350	0.0169
C & C	3	0.097	0.350	0.0169
Sum	31	1.000		

Ranks to SCW (Sub-criteria Weights)

Table 7 SCW of 32 Current Commuters

Current (Cyclist) Commuters						
Main Criteria	Median Stakeholder Rank	SDSS Weight (Rank/Rank Sum)	Sub-Criteria	Median Stakeholder Rank	SDSS Weight (Rank/Rank Sum)*MC Rank	Median Stakeholder Rank Uncertainty

Junc. Safety	6	0.211	Visibility	2	0.084	0.400
			Vol. & Speed	1	0.042	0.400
			Fac. Capability	2	0.084	0.400
			Sum	5	0.211	/////////////
D & E	4	0.140	Detour Factor	1	0.028	0.275
			Right Turns	2	0.056	0.275
			Delay	2	0.056	0.275
			Sum	5	0.140	/////////////
C & C	4	0.140	Connectivity	2	0.093	0.255
			Bus Stops	1	0.047	0.255
			Sum	3	0.140	/////////////
Attract.	4	0.140	Public Place	2	0.047	0.200
			Noise & Pol.	2	0.047	0.200
			Street Lights	2	0.047	0.200
			Sum	6	0.140	/////////////
Trip G & A	4	0.140	Population	1.5	0.070	0.175
			Destinations	1.5	0.070	0.175
			Sum	3	0.140	/////////////
Capacity	3.5	0.123	Eff. Width	2	0.082	0.250
			Traffic Comp.	1	0.041	0.250
			Sum	3	0.123	/////////////
Comfort	3	0.105	Roughness	2	0.070	0.100
			Non-slip	1	0.035	0.100
			Sum	3	0.105	/////////////
Sum	28.5	0.999				

Table 8 SCW of 18 Potential Commuters

Potential (Cyclist) Commuters						
Main Criteria	Median Stakeholder Rank	SDSS Weight (Rank/Rank Sum)	Sub-Criteria	Median Stakeholder Rank	SDSS Weight (Rank/Rank Sum)*MC Rank	Median Stakeholder % Rank Uncertainty
Junc. Safety	5.5	0.200	Visibility	2	0.073	0.250
			Vol. & Speed	1.5	0.055	0.250
			Fac. Capability	2	0.073	0.250
			Sum	5.5	0.200	//////////
D & E	4	0.145	Detour Factor	2	0.048	0.200
			Right Turns	2	0.048	0.200
			Delay	2	0.048	0.200
			Sum	6	0.145	//////////
C & C	4	0.145	Connectivity	2	0.097	0.100
			Bus Stops	1	0.048	0.100
			Sum	3	0.145	//////////
Capacity	4	0.145	Eff. Width	2	0.097	0.250
			Traffic Comp.	1	0.048	0.250
			Sum	3	0.145	//////////
Attract.	3.5	0.127	Public Place	2	0.039	0.200
			Noise & Pol.	2	0.039	0.200
			Street Lights	2.5	0.049	0.200
			Sum	6.5	0.127	//////////
Trip G & A	3.5	0.127	Population	1	0.042	0.300
			Destinations	2	0.085	0.300
			Sum	3	0.127	//////////
Comfort	3	0.109	Roughness	2	0.073	0.250
			Non-slip	1	0.036	0.250

			Sum	3	0.109	//////////
Sum	27.5	0.998				

Table 9 SCW of 16 Parents of 10-17 Aged Children

Parents of 10-17 Aged Children						
Main Criteria	Median Stakeholder Rank	SDSS Weight (Rank/ Rank Sum)	Sub-Criteria	Median Stakeholder Rank	SDSS Weight (Rank/Rank Sum)*MC Rank	Median Stakeholder Rank Uncertainty
Junc. Safety	7	0.226	Visibility	2	0.075	0.400
			Vol. & Speed	2	0.075	0.400
			Fac. Capability	2	0.075	0.400
			Sum	6	0.226	/////////////
Capacity	6	0.194	Eff. Width	2	0.129	0.450
			Traffic Comp.	1	0.065	0.450
			Sum	3	0.194	/////////////
Trip G & A	5	0.161	Population	1	0.054	0.500
			Destinations	2	0.107	0.500
			Sum	3	0.161	/////////////
D & E	4	0.129	Detour Factor	2	0.043	0.300
			Right Turns	2.5	0.054	0.300
			Delay	1.5	0.032	0.300
			Sum	6	0.129	/////////////
Comfort	3	0.097	Roughness	2	0.065	0.350
			Non-slip	1	0.032	0.350
			Sum	3	0.097	/////////////
Attract.	3	0.097	Public Place	1.5	0.024	0.500
			Noise & Pol.	2	0.033	0.500
			Street Lights	2.5	0.040	0.500
			Sum	6	0.097	/////////////
C & C	3	0.097	Link Length	2	0.065	0.500
			Bus Stops	1	0.032	0.500
			Sum	3	0.097	/////////////
Sum	31	1.001				

The rankings shown here are hierarchal and value-based. Thus, various performance measures can be formulated to fit their appropriate criteria rather than the performance measure defining the criteria and weights. For this test assessment the performance measures defined in the methodology chapter were used. However, these target cyclist ranks and weights can be applied with other, or improved, measures.

3.3. Breaking Down Route Performance to Junctions and Segments

By standardizing, weighting, and summing criteria scores per route and junction it is then possible to assess each component of the routes as well as obtain total route suitability scores per target cyclist group. To compare the performance of individual segments and junctions the 17 sub-criteria were plotted in line graphs to show how the individual criteria scores raise and lower between nearby segments and nearby junctions. Alternatively, these were summed and mapped. Smaller segment and junction scores indicate poorer bicycle-friendly performance when assessed against each group's criteria weighting scheme. For all three target groups there are dips in the route performance of those junctions connecting heavy-traffic roads (mainly Blenheim Rd and Riccarton Rd), with higher delays, more right turns, increased speeds and volumes as well as higher estimated noise and pollution. Segment scores suffered in parks and access ways. The following pages show the results for the target cyclist groups when their weight schemes were applied to the test area. First, a version with equal weights is shown for comparison.

Figure 19 Segment & Junction Scores: Equal Weights Map

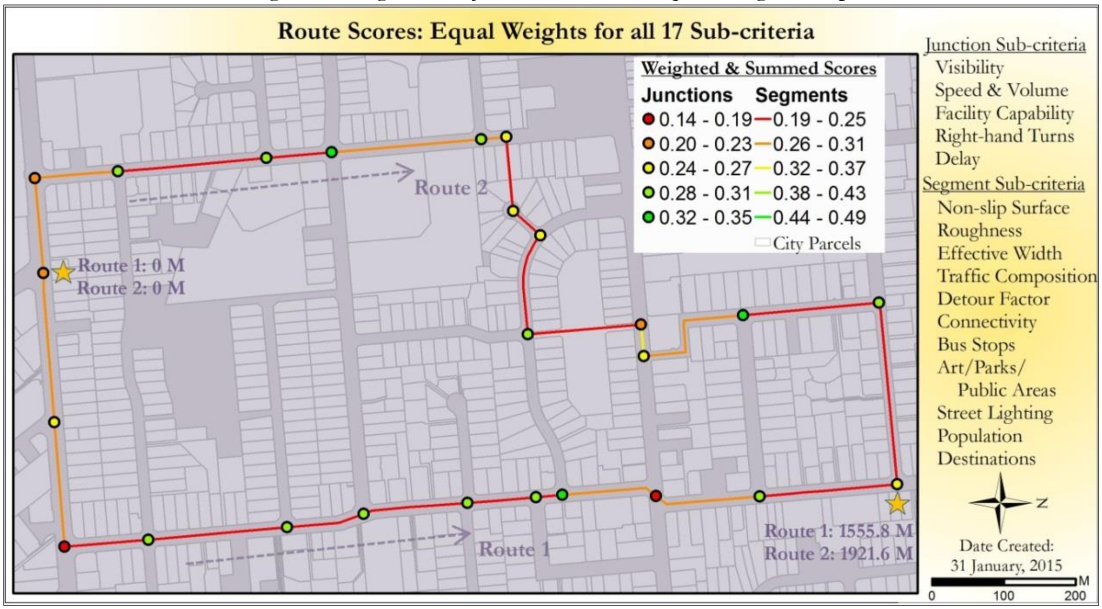


Figure 20 Segment & Junction Scores: Equal Weights Route 1

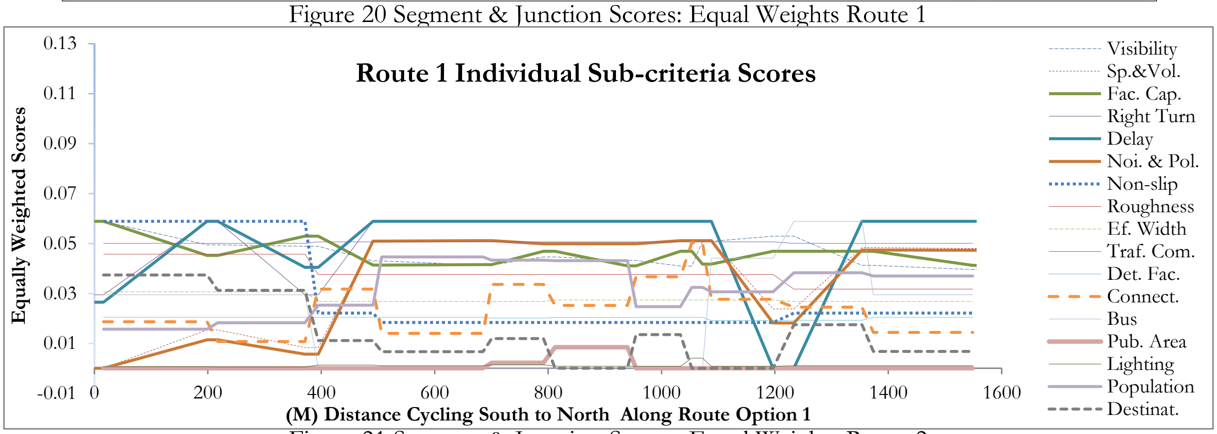
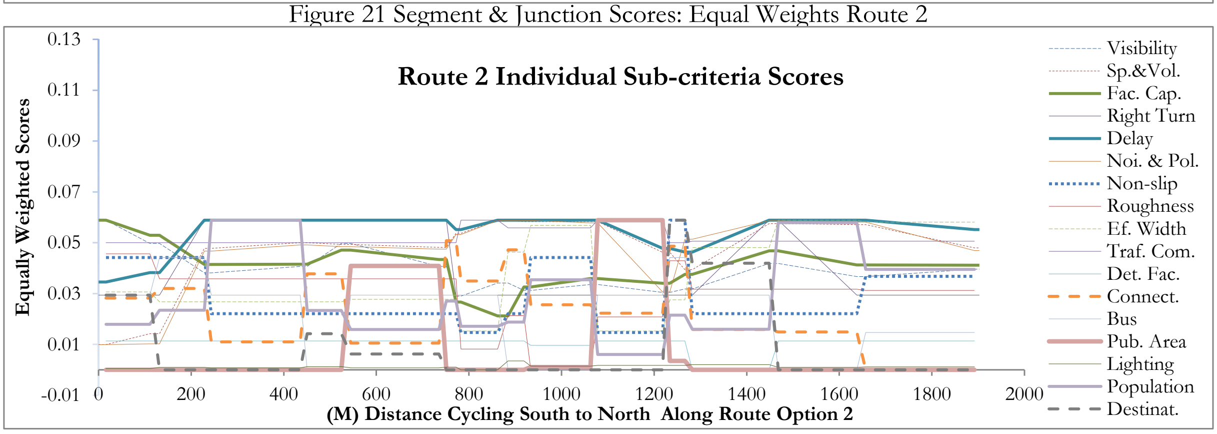


Figure 21 Segment & Junction Scores: Equal Weights Route 2



The above results are with equal weights and not yet transformed by the weighting schemes identified for the three different target groups. Since the summing of total route suitability results was pushed back to later in the procedure, it is now possible to visualize the individual sub-criteria scoring graphs and how they change with distance at different segments and junctions along each route. As can be seen in the summed version of these equal weight scores, many of the segments within this test area do not score very high in terms of bicycle-friendliness. This is because low scoring criteria such as lighting, adjacent non-residential destinations, as well as parks, art, and public areas (shown in the graphs as Pub. Area) are being displayed as equally important to Effective width, detour factor, and other sub-criteria. It was expected for these formerly mentioned criteria to score low as this procedure's test area is a fairly typical Christchurch residential neighbourhood which borders large industrial and commercial districts.

Figure 22 Segment & Junction Scores: Current Commuters Map

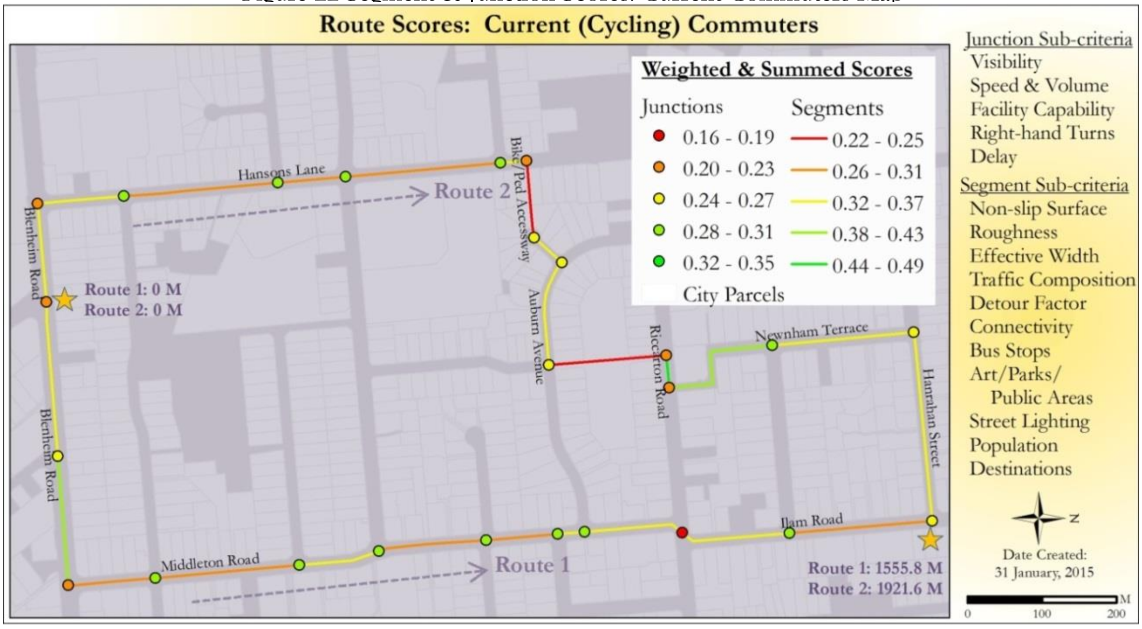


Figure 24 Segment & Junction Scores: Current Commuters Route 1

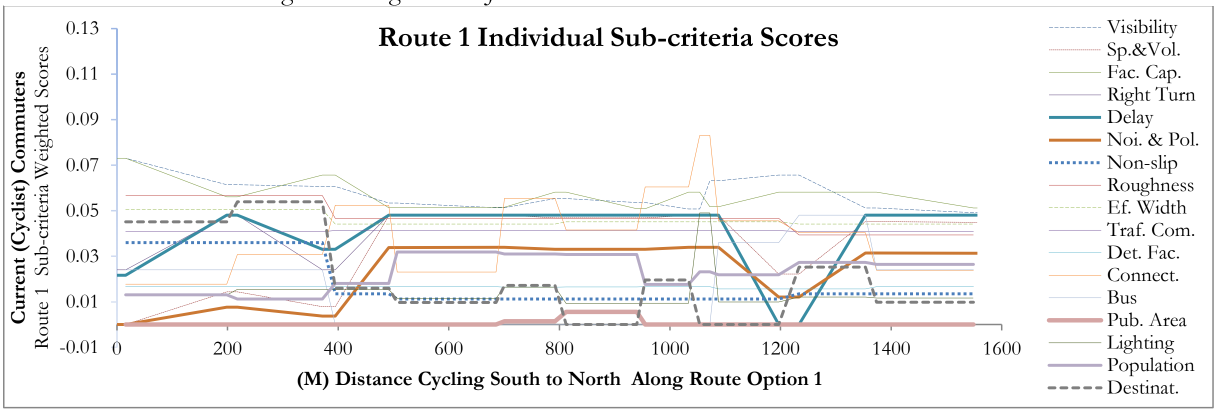
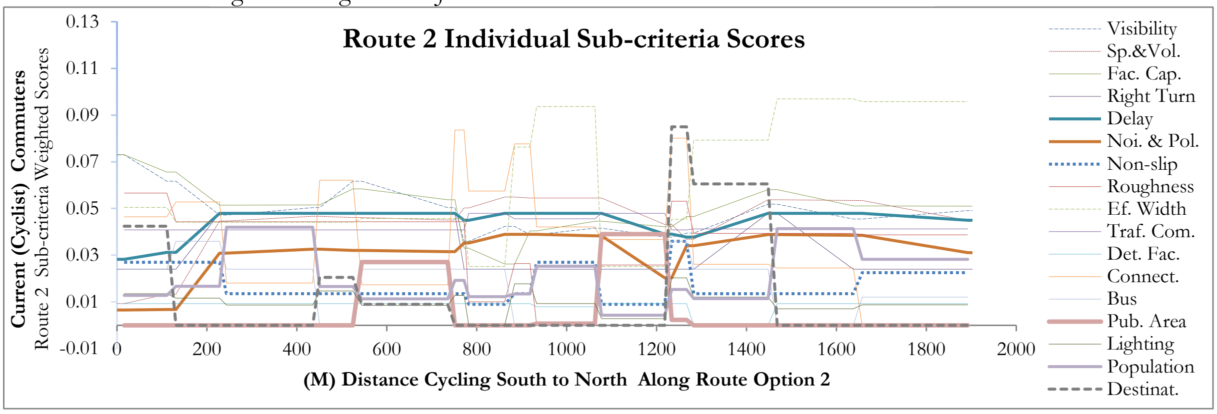


Figure 23 Segment & Junction Scores: Current Commuters Route 2



This page and the next two show the results after they've been transformed by the group weight schemes. Comparing the three target groups' results found inter-group differences. Lighting scored higher for current commuters than any of the others. The weighting schemes of both commuting groups is fairly similar. Surprisingly, the scores for delay at junctions were slightly less for current commuters than potential commuters, but it was only slightly and minor differences as these are likely due to the small sample size and respondent variability in their personal preference set ranking. Current commuters placed a higher importance on effective width, which favours wide and less trafficked road segments, and on route proximity to their destinations. "Near destinations" were defined in the ranking form to be "e.g. your child's school, stores, your workplace". The high score on these roads is potentially explained by current commuters' experience with utility cycling. They perhaps have a better understanding of what it is like cycling not just through their neighbourhood or for recreation, but on busy city streets.

Figure 27 Segment & Junction Scores: Potential Commuter Map

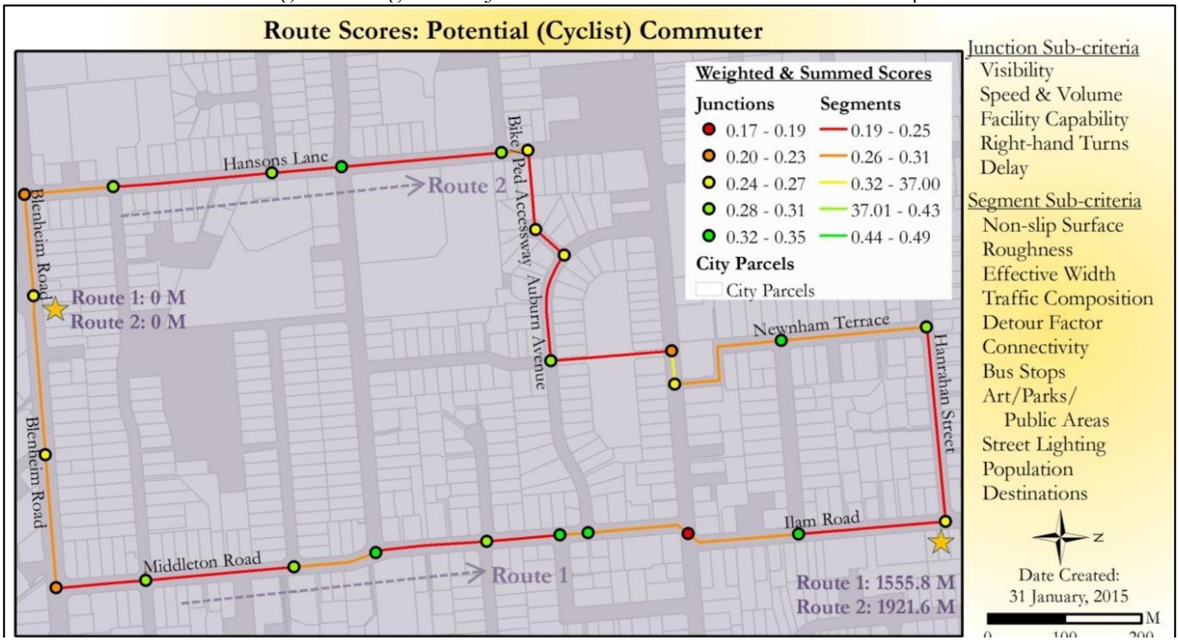


Figure 26 Segment & Junction Scores: Potential Commuter Route 1

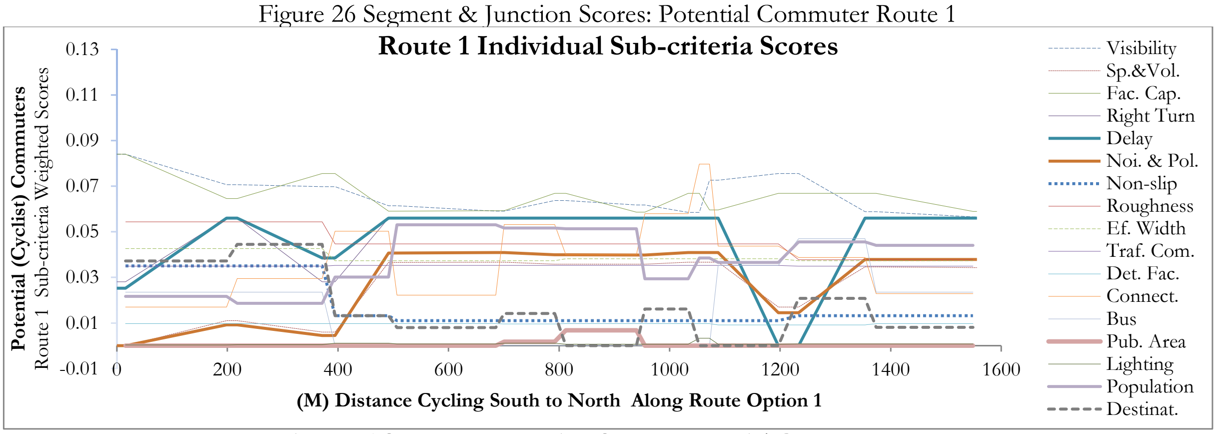
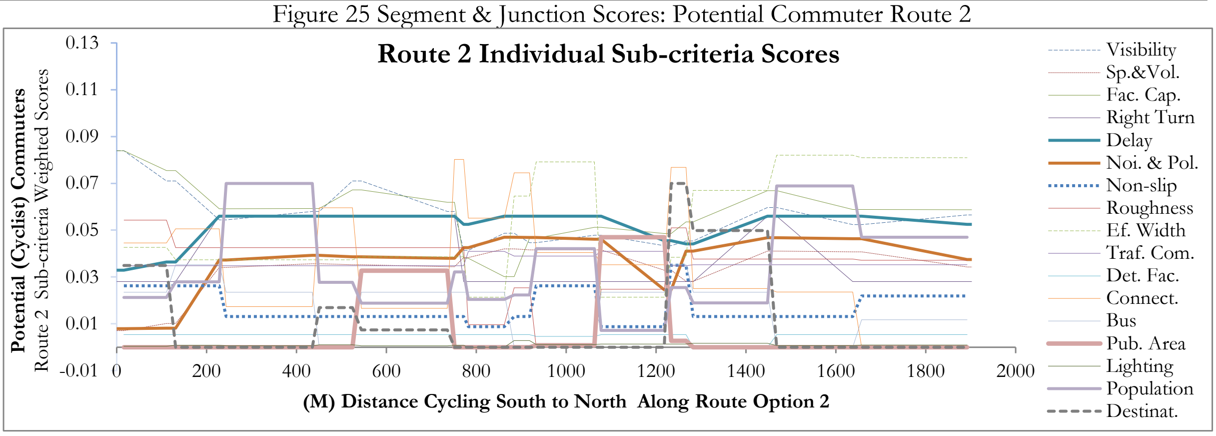


Figure 25 Segment & Junction Scores: Potential Commuter Route 2



The potential cyclists placed a higher importance on official cycleways having proximity to their home. This implies people who do not currently cycle to work/study could be enticed to start cycling if there were bicycle-friendly facilities near their home. Potential commuters had higher median ranks for facility capability and visibility compared to the current commuters, and this shows with higher scores for these criteria at junctions all long the two route options. Facility capability is scoring relatively high for both route options. This is true for all groups and is happening because the test area has fairly large junctions which could easily accommodate bicycle-friendly infrastructure. If this test area is representative, a majority of Christchurch's junctions would score well in facility capability. This is good news as one of the major design improvement areas identified the stakeholders was navigation through light-controlled intersections and assistance in crossing multiple lanes to turn right.

Figure 28 Segment & Junction Scores: Parents Map

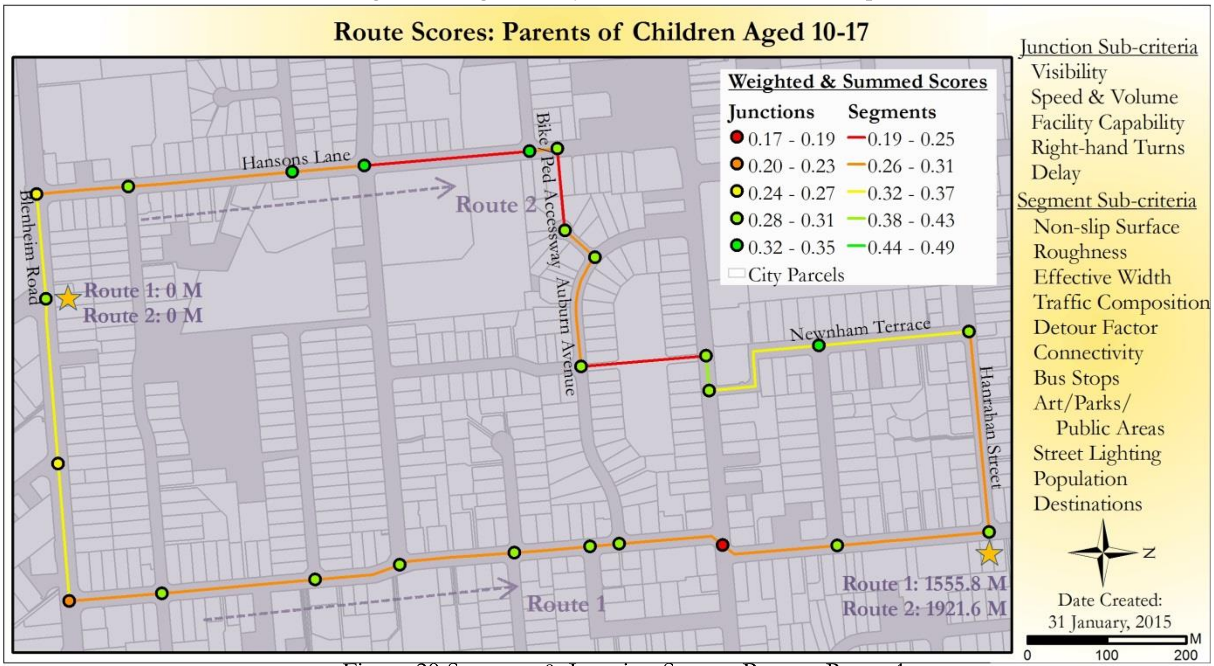


Figure 29 Segment & Junction Scores: Parents Route 1

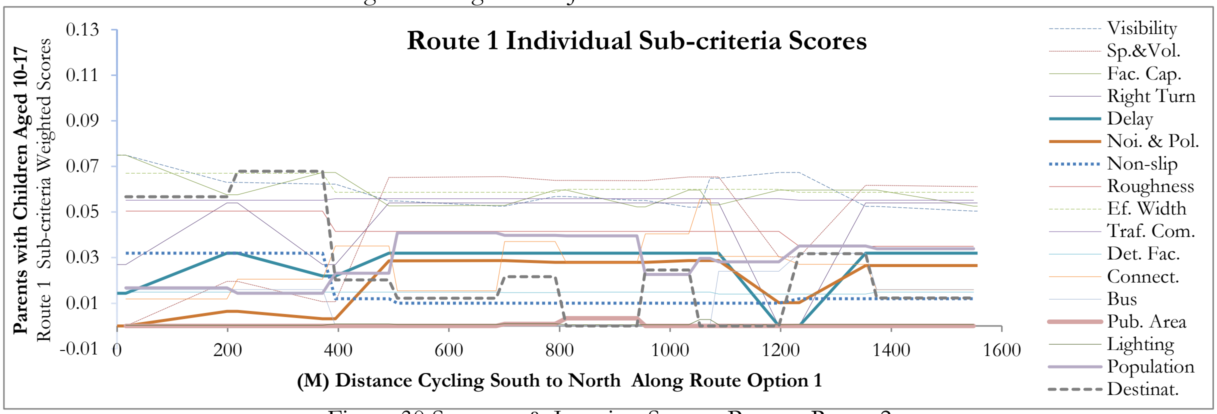
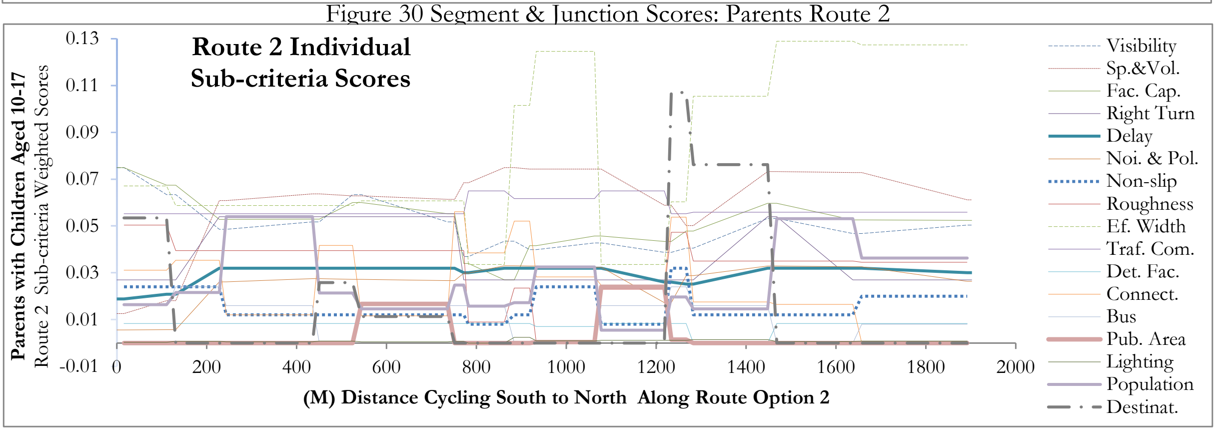


Figure 30 Segment & Junction Scores: Parents Route 2



For the parents effective width, speed and volume, and official routes near the destinations were important. Right turns were also a higher concern likely because the children would have to cross traffic and not all parents believe their children are mature, capable, or comfortable enough to manuvuer it. Detour factor was low on the parents' priorities, as were public space, art, and parks. Noise and pollution also scored less high for parents than the other two target groups. Though of the attractive sub-criteria the parents ranked parks, art, and public space as being the most important, with noise and pollution as second, and street lighting as third (with a 50% median certainty on the group's ranking of these three attractive sug-criteria). This is possibly because parks themselves are a kid's destination.

Figure 31 Segment & Junction Scores: All Weight Schemes Route 1

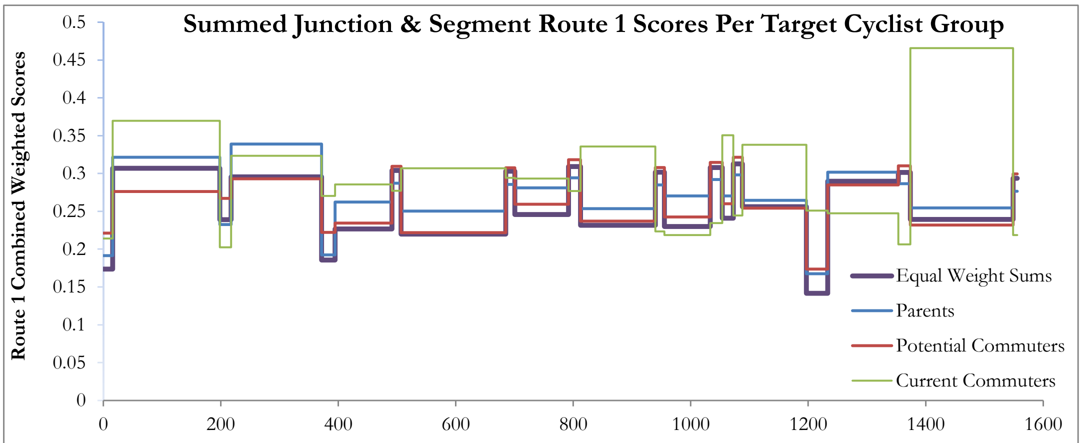


Figure 32 Segment & Junction Scores: All Weight Schemes Route 2

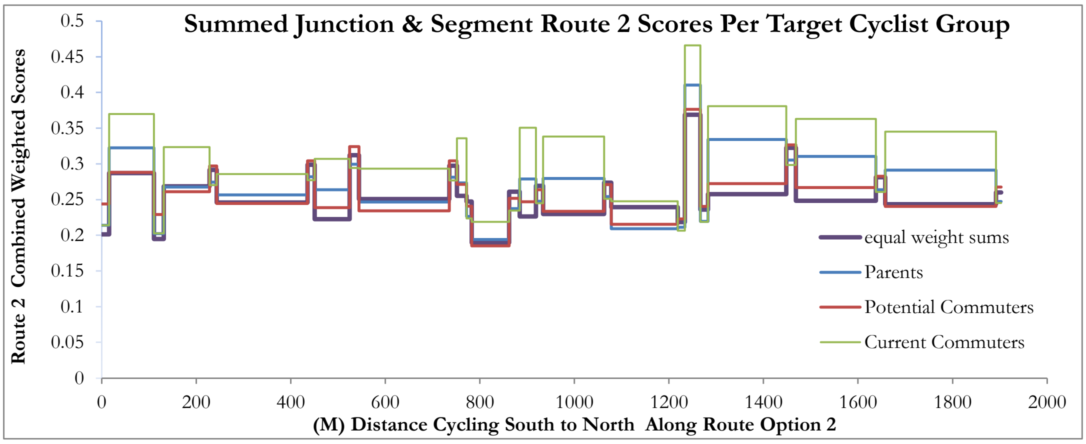
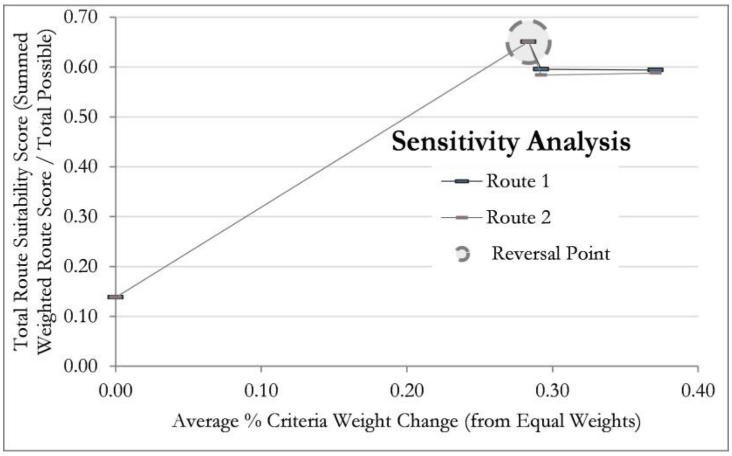


Table 10 Total Route Suitability Scores

Weight Scheme	Total Route Suitability Scores	
	Route 1	Route 2
Equal Weights	0.13841	0.13844
Current Commuter**	0.65093	0.65097
Potential Commuter	0.59580	0.58407
Parents of 10-17 Aged Kids	0.59417	0.58805

**Indicates Reversal Point (When the Best Scoring Route Changes)

Figure 33 Changing Weights for Sensitivity Analysis



The results indicate both of these routes perform better for the current commuter target group. When scored under both the equal weights and the current commuter weight scheme, route option 2's total suitability was narrowly higher than route option 1, but the scores were so close to be considered effectively the same. Route option 1 scored better for potential commuters and parents. Considering this, route 1 would be labelled as the "best" option for current bicycle-friendliness scored under these criteria and scored by the stakeholders of these three target groups. However, this total route suitability score does not account for the difficulties remaining for designers to transform the worst performing junctions (2 of which are on route option 1 and contain the heaviest traffic of the whole study area). Whether or not this stakeholder-defined suitable option is indeed the "best" option would be left up to the government decision makers heading the official cycle route project. Regardless, both route options score 6-7% higher for commuters than for potential commuters and parents of children 10-17. As stated in the previous pages, this is due to the type of roads in this study area and how they score better with the combination of criteria preferred by the current commuters. These results support the theory that not all roads are equally suitable for groups with different confidence and abilities (CROW, 2007). To accommodate these different groups, the city may do well to create a separate network of routes purely for the use of these less confident or able individuals.

These results demonstrate how different weight schemes raise or lower the total route suitability scores. This big shift in overall suitability was produced by the weights acting as linear transformations of the originial performance values. In other words, the cyclist preferences and weight schemes change, but the original road scores remain the same. When any set of route options is assessed using the same weight scheme, then the same transformation is applied to both routes' criteria. This leaves the potential for a reversal point (where the "best" option changes) to be caused by inter-route differences (the routes having different road types, transecting different neighborhoods, different densities of attractors and generators, etc). Weights change the total route suitabiltiy score and let it range from bad to good on the bicycle-friendliness scale of 0 to 1. Yet, the route's potential to be chosen as the "best" option is most heavily impacted by the route's characteristics and the performance of its junction and segment components, not so much by the weights.

When the routes' options go through the same neighborhoods and have similar road characteristics, the total route suitability scores are more likely to remain near each other (regardless of the weight scheme applied) and reversal points are more likely to happen. Consequently, longer route options are more likely to contain inter-route differences and produce more robust route suitability conclusions for decision makers. Hence, the total suitability score of a bicycle route is only as relevant as the scale it is applied at. For small areas, total route suitability becomes less relevant and summed scores of junctions and segments become more relevant. As a rule, a fairly homogeneous route (with stable criteria scores along its whole length) will produce more predictable, robust results no matter which weight scheme is applied. High inner-route diversity as was seen in route option 2 of this test assessment leads to less predictable results when weight schemes are changed. As the routes in this test area were chosen for their inner-route diversity, they were expected to show these distinctions by: 1) graphically displaying conflicting criteria along each route's length; and 2) representing how and why a reversal point could occur in real assessment situations. As stated at the end of the methodology chapter, presence of a reversal point would typically represent an unstable situation where one route option is not necessarily better than the other. In such an instance, designers and engineers would do well to look at the worst performing segments and junctions to see which of these could easily have their scores raised. Targeting segments and junctions in this way would increase the bicycle-friendliness of the whole route, and would make the route's total suitability more stable. Having multiple target group weight schemes and less robust results do not indicate a poor assessment, rather, they help alert official decision makers to existing deficiencies. These in turn provide opportunities to test how the overall suitability score would change once the worst segments and junctions are improved.

4. DISCUSSION

The last chapter presented the results and this chapter discusses the compromises which had to be made for this bicycle route assessment, including variance and the fundamental relationships between people, preferences, and criteria. This chapter will also discuss the assessment procedure's SWOT (Strengths, Weaknesses, Opportunities, and Threats), give a summary of major limitations, and present a list of future improvements.

4.1. Assessment Accounting for Variance

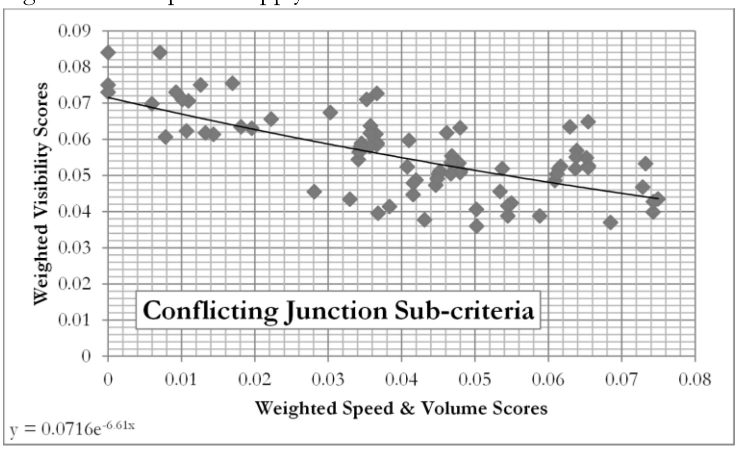
There will always be a variety of population needs and preferences which must be accommodated in public facility design. This variety requires assessment criteria and performance measures which can fully represent it. Between these focus group comments and the concerns mentioned in the cycling survey, a large number of needs and priorities were identified. The amount and diversity of criteria included in this study are thought to be sufficient to meet the different supply and demand-based concerns of Christchurch's population. Unfortunately, accounting for variable needs and preferences is not simple. There is a trade-off between high diversity of criteria and more manageable assessments with low criteria diversity. A highly detailed assessment with more criteria allows for more specific answers and higher variation between each two stakeholders' stated preference sets. An assessment with 5 sub-criteria would allow an individual stakeholder 120 total ranking alternatives to choose from. This assessment's 17 sub-criteria allows for significantly more preference set personalizations. High numbers of criteria introduce more heterogeneity into each target cyclist stakeholder group and require more stakeholders to receive population-representative answers.

The 66 stakeholders who participated in this study are unlikely to be fully-representative of Christchurch's entire population and further work is advised. To become representative of the city's population the stakeholder participation would likely need to be implemented on a large scale. This could be undertaken in the form of surveys or public opinion websites with more participants than the 66 recruited for this study. Without anticipating this type of sample bias, results from any assessment (even assessments with fewer criteria or other MCA techniques) may give misleading conclusions.

There are concerns about the validity of aggregating group preferences when the groups involved are not homogeneous in their opinions. This is a challenge for every policy-based assessment which incorporates stakeholders. Often the policies state generalized target groups which may be based off of traditional demographic and transportation studies, but fail to cover the depths of each group's personalized needs or preferences. This is a challenge which can only be overcome through more in-depth research and stronger policies. Future policies could first implement a factor analysis to identify distinctive population needs. Such policies would be more realistic and they would be truer to the population when implemented in pre-project infrastructure assessment. Only with improved strategic transport policies (which target homogeneous groups) can infrastructure assessments be both applicable to local project managers and statistically sound. Since there often is a separation between policy and reality, this thesis proposed the use of a reference value or midpoint value to be used for aggregating the preference scale. According to Mendoza and Martins (2006), this can be seen as a compromise for inner-group differences in criteria rankings. This particular method of AHP Fuzzy Set Theory and other aggregation methods are further discussed by Pomerol and Barba-Romero (2000), and Mendoza and Martins (2006). This thesis used the median for central tendency, but in stakeholder groups with normal preference distributions the mean could also be used for aggregation of personal preference sets. The use of a hierarchical value-based criteria tree made it easier to aggregate the highly variable stakeholder preference sets.

Due to differing preferences or engineering dilemmas, conflicts can happen on many levels and require compromises to be made. The introduction chapter highlighted the inherent conflicts commonly known to exist between supply and demand-based criteria (Rybarczyk and Wu, 2010). Interestingly, this study found how supply-based bicycle-friendly criteria could also conflict with each other. The graph below gives a simple example of this. It shows two desirable bicycle-friendly criteria working against each other, with the increase of one leading to the decrease in the other. Combining these sub-criteria will lead to a summed score somewhere in between these juxtaposed performance values. Generally, more road space also comes with higher average vehicular speeds. The results from this study give evidence to this general conflict. Even when applied to different weight schemes as shown here there remains a negative, non-linear, moderately strong correlation between increasing speed and volume with junction visiblity scores. Visibility, volume, and speed are some of the most important variables for reducing crash severity and fatality rates (Environment Canterbury, 2005; Ehrgott et al., 2012). These are commonly considered in the designs of facility engineering (Land Transport Safety Authority, 2004). However, as shown in the previous chapter's graphs, many criteria do conflict with each other in a single route option. Choosing one route will come with good scoring criteria, but it will almost always have poorly scoring criteria as well. Mitigating the effects of these compromises is the difficult job of facility designers and engineers. A standardised bicycle route assessment would be a way of structuring the complications and prioritisations involved with these compromises.

Figure 34 Example of Supply-side Criteria Conflicts



4.1.1. Towards the Creation of a Comprehensive Bicycle Program

While bicycling enthusiasts may get angered at these compromises they are a reality due to limited resources. Not every road can be fully equiped with bicycle facilities. Fortunately, many streets are natually bicycle-friendly. As stated by CROW (2007), smaller streets are inherently more bicycle-friendly than main arterials and likely don't need much in terms of additional bicycle facilities. Still, some small efforts may be made in the design of these streets so cycling seems more efficient and convenient than the car which most people in Christchurch currently use by default. The July 2014 cycle survey showed a significant proportion of Christchurch residents feel they live within cycling distance to work/study, but they don't regularly cycle there. This is happening in a city which (reputably) has more bicycle infrastructure currently in place than almost any other New Zealand city.

Simply installing cycle infrastructure does not seem to have improved Christchurch's cycling modal share thus far. If this strategy continues it likely won't be enough to make the whole city network bicycle-friendly enough for those potential cyclists to make it a competitive option against the car. The findings from this study give evidence to support smarter street design (such as chicanes or speed bumps that allow openings for cyclists to ride across them unimpeded, vehicular street calming, etc.) for neighborhood collectors as well as main arterials (narrowing of car space, barrier protected cyclelanes at intersections, etc). To make cycling more convenient priorities can be made including, but not limited to, the following:

- Changing the laws to give cyclists more right-of-way opportunities.
- Changing the laws to give cyclists more legal support if they're in a collision with a vehicle.
- Increasing the use of paint and signage to remind drivers they are sharing the road.
- Increasing marketing efforts to remind aggressive drivers those cyclists (who are annoying them) are people too. This is suggested because cyclists currently feel they have a dehumanised image.
- Lessons in school and on the Drivers License test in regards to driving around cyclists.
- Government purchase of accessways along the edges of key residential properties and the creation of bike/ped alleys to increase connectivity and cycling convenience.
- Widen the official cycleways so they will allow for disabled persons with electric wheelchairs to use them and increase the turning radius of corners so these electric wheelchairs can manuver properely. Currently most New Zealand cities do not give equal accessibility and mobility options for these individuals. Most cities either require them to go on slow speed sidewalks or on roads in the same lane as with the cars. According to Gerri Pomeroy, "Navigating intersections is the least safe component of a trip by wheeled mobility aid and hand-cycle" (Pomeroy, 2014).
- Improved and consistent city-wide design of official cycleways around bus stops and parked cars.
- Roadway speed bumps and chicanes which include skinny openings which are clearly marked for cyclists to pass unobstructed, thus showing priority and comfort to cyclists.
- Separate junction traffic so cyclists have their own phase of the light rather than having them share the time crossing with motorists. This approach has an advantage over shared-light Advanced Stop Boxes. Especially in cities where tensions exist, the inclusion of a cyclist-only light phase would focus the driver's agression on the light and not at the cyclist who just rode in front of them and "cut the line".
- Improved city maintenance of current cycleways and roads with an emphasis on street cleaning of broken glass and debris.
- Creation of a simple mobile app so the public can inform the city of areas which need work, and thus help city officials to make quick and easy project prioritisation. It is clear the public is willing and able to give constructive information since many of the focus group comments were location specific and detailed facilities at a certain site. The app could include a "suggested improvement" section where the reporter of the problem could list potential design improvements to the problem they see. This also provides a systematic way for the bicycle route designers to stay updated on the perceptions and difficulties of the population they are designing for. Furthermore, data would be generated which could be used to justify infrastructure projects to elected officials.

These improvements are directly related to the issues discussed by the focus groups—see full list of comments in the Appendix—and can be addressed on a national and a local level.

4.1.2. Assessment Procedure SWOT

Each multiple criteria assessment will have benefits, drawbacks, and a time range for which the results are relevant for. Due to uncertainty, changing roadway conditions, and shifting public opinions the results of each participatory MCA should be remembered as a snapshot in time. Multiple criteria assessments are not constants, things which change with the evolving situation. As Jankowski (1995) stated, “In many real world decision-making problems, criterion scores express predictions of impacts likely to be caused by the adoption of a given alternative and as such are prone to imprecisions of forecast and uncertainties of the future”. Keeping this nature of MCA in mind, below is a SWOT table of this study’s multiple criteria bicycle route assessment procedure.

Table 11 SWOT Analysis

Strengths	Weaknesses
• Approach is policy-driven & approved by local facility planners & designers, so is more likely to result in useful information • Criteria are internationally recognized as important, but if desired can be easily switched out, just as the stakeholder analysis can be reapplied in different localities, making the procedure applicable to other cities • Method is easy for Stakeholders and Policy Makers to understand, while still being relevant to transport engineers • Integrated multiple views & preferences on a wide range of bicycle-friendly criteria • Improved communication & understanding among many stakeholders to facilitate consensus building & policy compromises	• Uncertainties are not automatically corrected as they would be with pairwise comparison methods • This study assumes the stated preference sets are the individual’s true preferences given at the time, but these may change in the future • Same as how too a large number of criteria lessons an individual criterion score’s impact, the more stakeholders giving their preference sets, the less effect any individual’s preferences will have • Because the target cyclist groups are pre-defined in the strategic transport plan, there will inherently be more variation in the group preference sets than if the groups had been defined by like-minded preference sets or factor analysis • The process is initially slower than non-participatory planning & design
Opportunities	**Threats**
• Greater public satisfaction with the resulting bicycle facilities • Could provide a structured & transparent process for stakeholder participation • Improve public opinion of infrastructure projects & improve patience & livability of a city under post-hazard conditions • Provide a standard for regional and national bicycle planning & design • Results from future assessments could be the input to web-based applications and location-based service requests, thus helping the city know which infrastructure designs people like/dislike and also helping the government stay up-to-date on the population’s changing standards/expectations	• Slower projects are more prone to having their funding cut by the next city council or change in government agenda • There is a possibility the preferences of a few will outweigh real minority needs • The assessment is only as good as the policies and standards of the designers using it, such as in Christchurch where the standard bicycle lanes are too narrow for those populations in electric wheelchairs • Unless there is a national standard for the procedure, the current MCA results are unlikely to feed into the design of future MCAs • Currently there is no web platform within Christchurch to take people’s bicycle-related service requests/complaints and when there is a shift in public bicycle concern there is no structured way for them to inform the government, so the city has no way of knowing when preferences of target cyclist groups change

4.1.3. Limitations and Improvements for Future Assessments

First, and perhaps the largest limitation, is that an assessment based on current bicycle facility policies is only as strong as those policies. New Zealand's national framework for bicycle facility planning is outdated (Land Transport Safety Authority, 2004) and leaves the responsibility of design standards to be set locally. This means standards are drastically different across the country. What is acceptable in Christchurch may not be acceptable in Wellington. As much as possible this study attempted to include the national best practice measurement standards into the sub-criteria chosen from international literature.

Unfortunately, not all of the criteria which were thought to be important in international literature have any national measurement standards in New Zealand. This study assumes local engineers and designers will use their expertise and the information available to them to determine those sub-criteria measures which are not national standardized. Therefore this study focused its methodology explanation on those sub-criteria (noise and pollution, surface roughness, and flushing of non-slip surfaces) which did not have performance measures and data readily available and needed justifying. To test the assessment procedure for all 17 sub-criteria this research offered performance measures which could be used, but recommends future research is done to establish exactly what performance measures (because there are many) should become New Zealand standard to use on bicycle route assessments.

A further limitation is the detail of the assessment. The more criteria which are included, the smaller impact their scores will have on the overall route option suitability score. Hence, some important criteria may not hold as much weight as experts would like. This study did not define criteria which should have significantly higher weights. Some of these important criteria might include vehicle speed and volume and whether or not there is enough space for facility capabilities. If desired these significant criteria would have to be defined by the local experts. Most municipalities have transportation experts who are able to create sound supply and in-demand facilities for one type of cyclist group with specific needs and desires. Alternatively, it is much harder to design a cycle network for different needs and is especially hard to attract current non-cyclists to start cycling. Whether criteria importance should be defined by experts or by the public is something which must be discussed by New Zealand policy makers.

While this study put all 17 sub-criteria together in one assessment it would also be possible to make different assessments which are particular to the needs and preferences of different target cycling populations. This could help simplify the process and could also be directly relatable to policy objectives. Furthermore, maps of routes which cater to these specific needs or preferences could easily be generated and made available to the public. Right now Christchurch's official city website (Christchurch City Council, 2014b) does show cycle maps and list four routes they believe are family friendly, but the website does not specify the varying levels of facilities available on any of the given routes. Nor does it show the bicycle-friendliness of any common street in the possibility cyclists are trying to make their own route. Since the city is in the process of developing its cycle network, multiple types of routes could be created. This would give different levels of service and essentially provide more diversity of available facilities within the city-wide cycle network. Different levels of facilities may be the solution to catering to different types of people and their criteria needs and preferences.

4.2. Applying Assessment on City-wide and National Levels

Although the test area shown in this thesis did not need spatial constraints they must be considered if applying the assessment to the network scale. Constraint criteria must be dealt with prior to the generation of route options and prior to the computation of compensatory criteria scores. If any section of roadway is too hazardous or too expensive to provide bicycle-friendly infrastructure then it must be cancelled from the possible route locations with a Boolean operation. Depending on local concerns there can be any number of these constraint criteria and the ranking of the compensatory criteria will not be affected.

The largest benefit of MCA is its ability to provide a structured process in the face of conflicting criteria and stakeholder priorities. Since this study's assessment is value-focused and not alternative-focused (M. Sharifi and Boerboom, 2006) this can be applied to route options in any city with the same values with the only alteration needed at the stakeholder analysis phase. The route assessment procedure proposed here is flexible so criteria can be removed or altered and preference sets can be assessed with more extensive analysis so the results can be representative of entire city populations.

The assessment is ideal for use by road experts as local situations can play a heavy role in what criteria should be input and the experts may have to decide how they should be calculated. For instance, the level of chipsealing required for safe and skid resistant surfaces differ for different types of roads, their traffic stress, duration and intensity of the roads' sun exposure, and whether or not they have bridge decks, railway crossings, etc. (Transit New Zealand et al., 2005). The practice of designing bicycle routes is inherently subjective to what the designers and engineers view as important to include in the assessment. However, the subjectivity of including different performance measures can be structured on a national scale so everyone understands exactly what standards were included. This would allow more faith to be placed in the consistency and quality of these pre-project assessments. Without some kind of nationwide assessment bicycle routes will still be designed with a priori criteria importance, but the quality of the work will continue to be dependent on locally available experts and will likely vary from project to project.

5. CONCLUSION

A real route is not simply one aggregated score, but is the sum of its many diverse parts and its bicycle-friendliness can change over space and time. Consequently, route designers are better equipped if they have access to quantitative spatial assessments which: 1) give detail at the junction and segment level; 2) can easily take new performance values for changing conditions; and 3) can be used as an exploratory tool for hypothetical future scenarios. Designers and engineers will be confronted with route options, but the total suitability of any route is likely to change once improvements are made to the worst-scoring junctions and segments. Being able to play around with these junction and segment scores can give a more realistic view of how the route's bicycle-friendliness will improve if investments are made. This can strengthen the justification for city-wide cycle programs and can encourage public support for any individual construction project. To improve the bicycle-friendliness of a whole city network, this route assessment could be applied to: 1) identify currently bicycle-friendly roads which could be combined with small repairs or added access ways to become full routes; and 2) implement policy-defined thresholds requiring streets or routes to meet certain standards for safety and other concerns; and 3) keep up to date on the perceptions and needs of different target cyclist groups.

To strengthen the New Zealand planning and design process, this thesis began the development of a multiple criteria bicycle route assessment procedure for Christchurch. It reviewed currently used methods and chose criteria relevant to Christchurch's bicycle network goals, planning policy, engineering standards and managerial objectives. This study integrated the chosen criteria within a new procedure and applied them to the test area within Christchurch. It displayed how the participatory assessment can be used and broken down to junctions and segments, then discussed the implications and how the route assessment could be scaled to whole city networks and used for national policy enforcement. The last chapter critically evaluated the procedure and its assessment, discussing its results and implications.

Christchurch and many other New Zealand cities are looking to encourage more people to begin cycling, mainly through education and infrastructure investment (Canterbury Regional Transport Committee, 2012). Unfortunately, there is no national framework for legally regulating efforts towards the planning, design, and implementation of bicycle facilities. The quality of regional cycle projects is dependent upon the experience and judgements of the locally-available experts. Considering the results of this study, future research is recommended to investigate which performance measures could be implemented as standards for all of New Zealand. Future studies can explore the dynamics of implementing standardized bicycle-route assessment procedures in different situations and different city environments. It would be especially interesting for policy makers to better understand how stakeholder participation can be applied on a city-wide scale. Standards need to be better defined in order for quantitative bicycle route assessments to efficiently operate within city management. Although assessment results support the monitoring and processing of detailed data, ultimately reaching strategic transport targets require laws and policies to give a strong and comprehensive foundation. Without this, cycle programs will continue to rely upon "bright ideas and pet projects that may not have been critically evaluated for usefulness and value for money" (Land Transport Safety Authority, 2004). Once these comprehensive planning strategies are in place and they are utilizing high-standard quantitative assessments New Zealand's mobility options will drastically change for the better.

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KEY DEFINITIONS

Bicycle Route—a combination of links (road segments) and nodes (road junctions) which have been provisioned with facility infrastructure which has been officially designed and designated by the local government or ruling transport agency
Cardinal Data—quantitative and usually assessed through precise measures of utility functions
Criteria (compensatory technique)—a standard of judgment or rule on the basis of which alternative decisions can be evaluated and ordered according to their desirability (Malczewski, 2006), it is more cognitively demanding because stakeholders must specify criterion priorities as cardinal weights or value functions (Jankowski, 1995)
Criteria Standardization—transformation of each criterion into a unitless value score so they may be combined into the option/alternative's overall suitability score (S. Hajkowicz and Higgins, 2008), the poor performance of one criterion can be compensated by a good performance of other criteria (Geneletti, 2010)
Constraint—a criteria or variable which is noncompensatory, or under conditions of strict dominance, and has the potential to cancel out the usefulness of the other criteria being assessed (Pomerol and Barba-Romero, 2000; S. Hajkowicz and Higgins, 2008), and as such can be included in thresholds via value functions but cannot be ranked, and all domination options should be spatially excluded from the decision set before the MCA is applied
Current (Cycling) Commuter—an individual 18 years or older whose main mode of transportation to work/study is bicycle. These individuals cycles to work/study at least once a week
Decision Maker—the person who will make the final choice between the options or alternatives available, a decision which may be influenced from the knowledge gained during the MCA, but whose final choice may not only influenced by the MCA
Flushing—loss of road surface texture, often for macrotexture decreases with chip embedding (Transit New Zealand et al., 2005)
Fuzzy Uncertainty—uncertainty associated with imprecision concerning the description of the meaning of the events, phenomena or statements themselves (Malczewski, 2006) or when there are differences in the preference sets of a group (heterogeneity) (Mendoza and Martins, 2006)
Group Decision Making—when problems are given to different stakeholders (individuals or interest groups) who are characterized by different goals and criteria preference sets (Malczewski, 2006)
Microtexture Skid Resistance—fine texture caused by irregularities on the surfaces of each individual chip, and along with Macrotexture, these are the two texture scales which influence wet-road skid resistance (Transit New Zealand et al., 2005)
Multiattribute Decision Problems—are discrete choice sets which are assumed to have a predetermined, limited number of alternatives (S. Hajkowicz and Higgins, 2008; Malczewski, 2006)
Multiobjective Decision Problems—are continuous choice sets (considered as continuous in the sense that the best solution may be found anywhere within the region of feasible solutions) (Malczewski, 2006)
Multiple Criteria Assessment—an analysis procedure which evaluates the suitability of different options or alternatives through the scoring of diverse value or alternative based variables (known as criteria)
Ordinal Data—qualitative and usually assessed through non-precise, relatively ranked measures
Parent (of Child Between 10-17 Years Old)—an individual who stated they had at least one child between the ages of 10-17, including both parents with cycling and non-cycling children
Performance Measure—a decision option's raw score against a criterion (Hajkowicz and Higgins, 2008)
Polishing—Loss of microtexture of road surface and measured by Polished Stone Value, which gives an indication on a scale of 0 to 100 of how polish-resistant the chip is expected to be, look further in the

TNZ T/10 specification guidelines to find appropriate PSV for any given situation (Transit New Zealand et al., 2005)
Potential (Cycling) Commuter—an individual 18 years or older whose main mode of transportation to work/study is something other than cycling, who either irregularly cycle or who do not cycle at all, these include recreational cyclists who do not currently cycle to work/study
Preference Set—the stated priorities from a decision maker (or the stakeholder as is the case in this study) that is usually represented in a preorder and which reflects which criteria are most important to them
Probabilistic (stochastic) Uncertainty—uncertainty associated with limited information about the decision situation (Malczewski, 2006)
RAMM—used generally to aid engineers in prioritizing which roads will receive treatment projects, in New Zealand the Road Asset and Maintenance Management systems are locally up kept databases of roading assessment information
Ranking—the listing of compensatory criteria in the order of their importance
Reversal Point—the weight scheme at which a shift in the most suitable option occurs, this suggests instability in the answer of which option is "best", and if the routes remain in their current state then neither are the robust option for most bicycle-friendly when scored under these criteria and weights
Sensitivity Analysis—considering all alternatives taking part in the evaluation process and calculating changes in their ranking positions as the result of changing criterion scores and criterion weights (Jankowski, 1995), and if they do change with only small weight changes the scores for those criteria are not robust and should be used with caution
Spatial Decision Support System—a platform for geo-information to be input, analysed, and output in a way which is beneficial to the decision maker
Stakeholder—a person who has an interest in the outcomes of the decision problem and who likely has their own views and preferences which will determine their satisfaction of the final decision to be made
Sub-criteria—a criteria which has been hierarchically categorized to be under the "umbrella" value structure of another, usually more general, criteria
Suitability Score—a measure of the overall benefit or worth of a decision problem
Value Statement—identifies a goal or objective and an indicator that ranks the performance of the road segment or junction in relation to the goal (Beukes et al., 2013), it is the framework or viewpoint which becomes the basis of a criteria's performance measure
Weights—a set of multiplication factors to be applied to normalized and comparable compensatory criteria scores, usually based off of a ranking or value function

Appendix A: Choosing Criteria for the Procedure

Part 1: Canterbury Regional Approach to Supply & Demand Interventions

The *Canterbury Regional Land Transport Strategy 2012-2042* report states, "The strategic direction is to improve mode choice, enable choice around destination of travel and provide for alternatives to travel such as tele-working. Implementation of this strategy relies on improvements to the strategic network, investment to enable walking, cycling transport as well as interventions that manage demand."

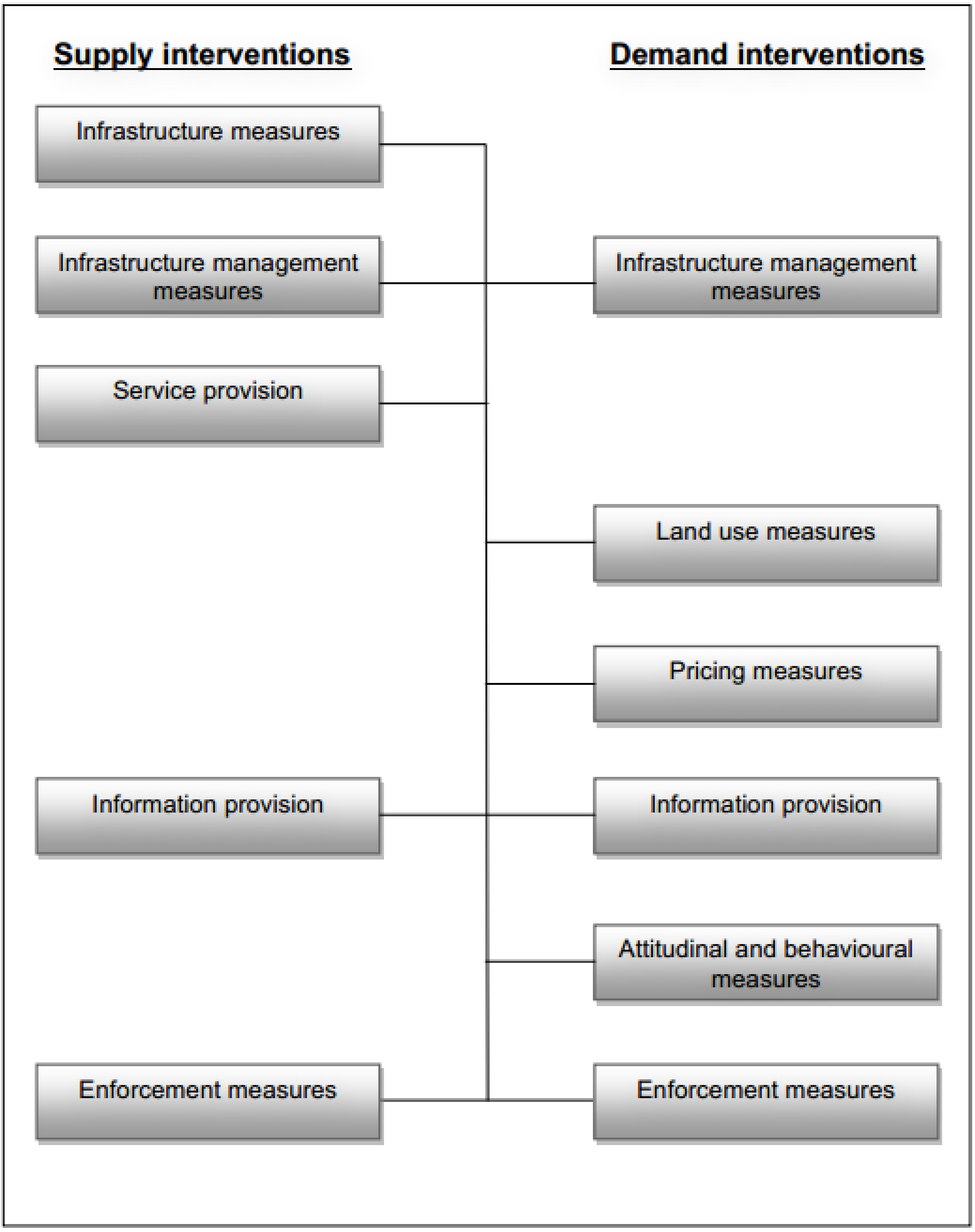

Figure 35 Supply & Demand Interventions, From Pg. 47 of the Technical Appendices (Canterbury Regional Transport Committee, 2012)

NZ Best Practice Bicycle Facility Planning Procedure

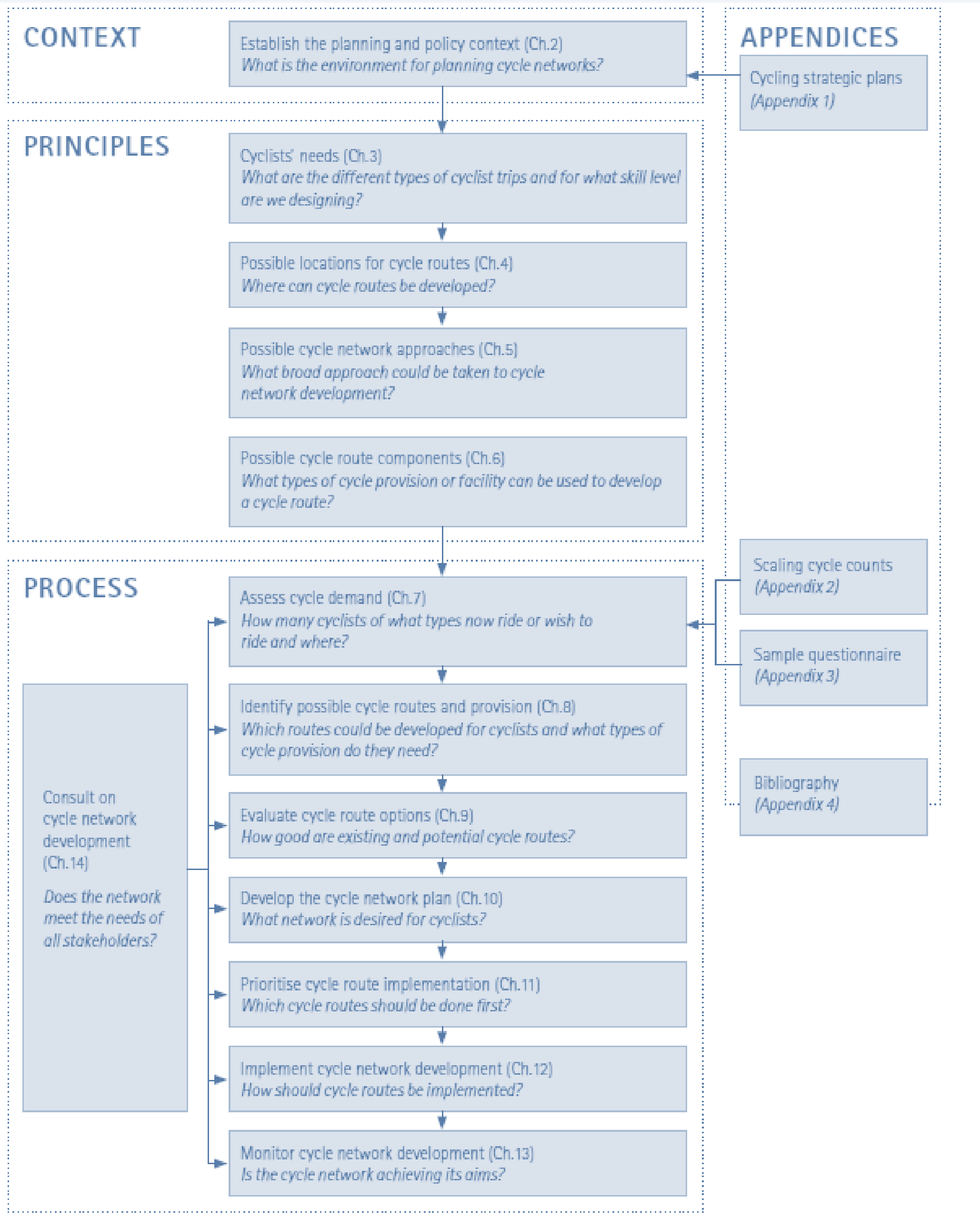

Figure 36 New Zealand Advised "Best Practice" Guideline for Bicycle Planning (Land Transport Safety Authority, 2004)

Appendix A: Choosing Criteria for the Procedure
Part 2: List of the 49 Sub-criteria Considered for this Assessment Procedure of which 17 were chosen for Christchurch

Type	Sub-criteria/Performance Measures	Documents or Publications supporting their use	using?	Why using or not using?
Supply-side	Smoothness of Ride (Carriageway Roughness)	(CROW, 2007; Ehrgott, Wang,	yes	Comfort of this sub-criteria heavily affects enjoyment of riding.

		Raith, & van Houtte, 2012)		
	Pavement Quality (polishing, flushing, cracking, potholes, etc.)	(CROW, 2007; Ehrgott et al., 2012)	no	These conditions may be more influential during (or caused by) poor weather conditions and their presence heavily depends on the quality frequency of road maintenance.
	Maximum gradient and tilt	(CROW, 2007; Ehrgott et al., 2012; Fernández-Heredia, Monzón, & Jara-Díaz, 2014; Menghini, Carrasco, Schüssler, & Axhausen, 2010; Winters, Davidson, Kao, & Teschke, 2010)	no	Much of Christchurch is relatively flat. This sub-criteria would have to be included for a nation-wide MCA procedure, because of cities such as Wellington.
	Non-slip Surface or Skid Resistance	(CROW, 2007; Ehrgott et al., 2012)	yes	It affects whether or not people feel comfortable enough to ride, especially during poor weather conditions.
	Curb radii	N/A	no	This author could find no documents supporting its statistically significant influence on riding comfort.
	Drainage Capacity (so water cannot sit and freeze)	N/A	no	While this sub-criteria could heavily impact winter riding comfort, there was not enough previous uses to support its inclusion.
	Exceeds minimum roadway width and assumed ability to separate traffic types and speeds	(Belon, Nieuwendyk, Vallianatos, & Nykiforuk, 2014; Ehrgott et al., 2012; Menghini et al., 2010)	yes	Justified because the amount of space given to Christchurch cycle lanes and paths have greatly varied in the past. In some places the cyclist has just a meter and they are essentially riding on the shoulder of the roadway.
	Below maximum roadway width for on-road cycle lanes, so routes parallel to Highways & Interchanges must have separate cycle paths	(Belon et al., 2014)	no	Scope of study is restricted to urban roads and no highways are within the tested area.
	Separation from on-road parking	(Ehrgott et al., 2012)	no	Much of the parking will be removed to make room for the cycleways, so carriageway width and reserve width are better performance measures.
	Presence of paved shoulder with minimum width	(Environment Canterbury, 2005)	no	Most streets within Christchurch have these.
	visibility near modal convergence points where separation becomes zero (intersections or decreasing road width or disappearance of cycle lane), distance needed depends on traffic speed allowed	(Belon et al., 2014; Pont, Ziviani, Wadley, Bennett, & Abbott, 2009)	yes	Crucial for crash avoidance, though it may be hard to make measurements comparable across whole study area. Belon et al. (2014) found it encourages engagement and creates a safe atmosphere. Pont et al (2009) gave evidence how those with poorer peripheral vision, such as the young or the old and those who have less ability

				to judge speeds accurately, that all of these are more prone to acting impulsively compared to regular cyclists) and need greater provision of visibility from a vehicle to avoid collision.
	presence of parking capacity and turnover (parking time limit)	(Parkin, Wardman, & Page, 2007b)	No	Although parking increases perceived risk when cycling through residential areas, parking will likely be removed on the Christchurch main cycle routes, because the city officials believe there is not enough space.
	Speed and volume of intersections	(Environment Canterbury, 2005; Ehrgott et al., 2012)	yes	Increased speed and volume has a strong, positive correlation to severity of cyclist injuries in motorist/cyclist collisions.
	Proportion of junctions with bicycle facilities (both signalized and not)	(Parkin et al., 2007b)	no	Of secondary or no importance. Page 6 of Parkin (2007b) states facilities at junctions were not valued for reducing perceived risk.
	Number of side roads passed	(Parkin et al., 2007b)	no	Of secondary or no importance. Page 6 of Parkin (2007b) states number of side roads passed was not valued for reducing perceived risk.
	Number of pedestrians present	(Parkin et al., 2007b)	no	Of secondary or no importance. Page 6 of Parkin (2007b) states number of pedestrians present was not valued for reducing perceived risk.
	Street lighting	(Parkin et al., 2007b; Belon et al., 2014)	yes	So use of bikelanes can extend beyond daytime hours. Belon et al., 2014 (Poor street lighting discouraged respondents from cycling, as well as other people in their community worried about crime) and disadvantages those who do not work during the daytime hours.
	Detour factor per road segment (preferably no more than 1.2)	(Pont et al., 2009)	yes	Pont et al 2009 (Increasing distance needed to get to a destination is inversely related with rates of children's cycling), especially young, inexperienced or uncomfortable cyclists.
	directional delay at intersections & Route's summed wait time at intersections / Route length or # Intersections (each intersection multiplied by # of lanes for complexity level, then the individual results are aggregated and divided by route length)	(Ehrgott et al., 2012; CROW, 2007; Landis et al., 2003; Pucher et al., 2010)	yes	Landis et al. (2003) states it matters past a certain threshold and Pucher et al. (2010) details how decreasing the number of stops matter.
	# right-hand intersection turns (for delay), also correlated with safety	(Parkin et al., 2007b)	yes	Page 6 of Parkin (2007b) states "number of right turns on a journey has a significant effect on the perceived risk, much more so than the risk from passing through signalized junctions."
	Grid-mesh width of this part of the network	(CROW, 2007)	no	This is more useful when analyzing a whole network, rather than route scale.
	Route's average distance between connecting streets which can be used by cyclists	(Christchurch City Council, 2012; Badland,	yes	Badland et al. (2008) reported "Cyclists who travelled less than 1 km to their occupation were significantly more

		Schofield, & Garrett, 2008; Saelens, Sallis, & Frank, 2003)		likely to travel through the most connected street networks…A certain street connectivity ratio threshold may need to be achieved before TPA engagement becomes feasible for the adult population" in New Zealand. A route must be accessible and well connected to those other parts of the transport network.
	# Links with free "park and ride" car parking lots	(Christchurch City Council, 2012; Pucher et al., 2010; Belon et al., 2014)	no	The city wants the travelers to easily transfer between the different networks offered. But they do not yet have a park and ride established, so only use bus data.
	# Links (per total route length) with public transport network **or** density of bus stops (within 400 km of route)	(Christchurch City Council, 2012; Pucher et al., 2010; Belon et al., 2014)	yes	
	Continuity of design for lanes/intersections with paint and signage and warnings for cars that cyclists may be crossing	(Belon et al., 2014)	no	Assume cycle lane's future design and signage will be up to standard.
	Distance from high-speed & busy motorized traffic nuisance (noise & pollution sources)	(Winters et al., 2010; Belon et al., 2014; Canterbury Regional Transport Committee, 2012)	yes	Local studies indicated there are likely vulnerable populations which would suffer from increased exposure to noise and pollution. See MCA Analytics section for the full paragraph detailing this. Negative health effects, particularly from heavy vehicle proximity, should be avoided or mitigated as far as possible.
	Highly visible, good bicycle parking	(Fernández-Heredia et al., 2014)	no	Because bicycle parking facilities should be placed around the places in which bicycle is used and Christchurch is just beginning their bicycle-friendly infrastructure and is not likely to have much bicycle parking outside the city center.
	Traffic composition (% non-truck traffic)	(Environment Canterbury, 2005; Ehrgott et al., 2012; Canterbury Regional Transport Committee, 2012)	yes	Emissions tend to be greater with truck traffic and are a detriment to cycling attractiveness.
Demand-side	Presence of parks, public areas, or urban green space	(Belon et al., 2014; Broberg, Salminen, & Kyttä, 2013)	yes	Under 18 year olds are attracted to these areas.
	Route suitability due to nearby land-use incentives. Beautiful scenery/building areas are prioritized and higher suitability scores are assigned to the route. **or** Proportion of residential : commercial mixing with 1 : 1 as neutral	(Winters et al., 2010; Belon et al., 2014; Broberg et al., 2013)	No	Not Suitable Diversity present in problem area, but Belon et al 2014 (The presence of these were "not only assessed in terms of beauty; functionality of urban green areas was also considered, such as provision of natural shaded areas"); Is deemed important for cycling incentives and can

				help with closely-related policy goals, though it may be hard to make qualitative rating comparable across whole study area.
	Presence of mixed land use	(Saelens et al., 2003)	no	Saelens et al (2003) higher rates of cycling commercial facilities nearby and with increased mix of land uses. Badland et al (2008) Those in mixed land and high density environments tend to use active transportation, but these seem to be co-dependent variables. Only use density since mixed-land use usually follows after density, and use density only if a proxy for demand is needed. However, if the purpose of the trip is solely for shopping or other utility errands, then mixed land use could be very important. People are more willing to travel longer distances to work than to everyday errands like shopping. Demand studies which span across large distances will likely not have mixed land use as a significant correlation to cycling. High densities may indicate higher numbers of active travel for short trips, but origin density becomes irrelevant to trip mode choice if the destination is far away.
	Population Density	(Badland et al., 2008; Saelens et al., 2003)	no	
	Type of Residential & Commercial development (distance between units **or** building density)	(Broberg et al., 2013; Pont et al., 2009)	No	Not applicable to test area, but Broberg et al (2013) states it has an effect on children's ability to be mobile, and older children have higher affordances when density is scrutinized as floor area ratio, suggesting younger children concentrate on residential areas for their cycling and older children concentrate on commercial or central areas for their desired destinations. Pont et al (2009) says there is evidence for mixed or commercial land-use to have a possible significant positive association with children's cycling, but results on the significance of the association vary between studies.
	Proportion of cyclist types, trip types & frequencies (possibly from scaling cycle counts as displayed in LTSA's cycle planning guide)	(Land Transport Safety Authority, 2004;Fernández-Heredia et al., 2014)	no	Not explicitly an assessment criterion. Will be included naturally in the weighting schemes or their influence mentioned in the resulting report.
	Current cycling demand with neighborhood populations commuting to work	N/A	no	Could not find publicly available data which was not de-aggregated from district level (such as what was used in the CAST forecast).
	Potential Demand with population (#/km within certain distances of the road segment, these distances would be defined per a value function of biking distance to cycling	(Belon et al., 2014; Pont et al., 2009)	yes	Pont et al (2009) claimed "Increasing distance to destination was frequently examined physical environmental determinant." And knowledge of facilities within the proximity significantly increased girls aged 10-15

	infrastructure, ex: 400m from road segment) **or** a gravity model like Latent Demand Score (LDS)			rates of cycling to school. "Children whose parents reported walking and biking facilities in the neighborhood were two and a half times more likely to walk or bike to school at least once a week compared with children who did not have such infrastructure."
	Diversity of destination types available to route	N/A	no	These were one of the major reasons for choosing the test area and the route options within it. They were recorded during research for this purpose. However, including them in the assessment would potentially have shown researcher bias.
	# Non-residential Destinations adjacent of the road segment	(Rybarczyk & Wu, 2010)	yes	Because demand at segment and junction scale required this level of de-aggregation, in order to draw out differences of segments within a single route.
	Presence of industrial or hazardous zones	N/A	no	It was discussed during the meeting with the Christchurch city officials, but there were no hazardous areas near the test area.
	Areas defined by survey respondents to be perceived as unsafe or areas of high crime	N/A	no	This was included in the stakeholder analysis in terms of unsafe infrastructure, but unsafe neighborhoods were not included in the assessment procedure because the perceived dangerous areas identified during the meeting with Christchurch city officials were not near the test area.
Other	Driver behavior and drivers' lack of awareness	(Belon et al., 2014; Parkin et al., 2007a)	no	Assumed constant across entire problem area. Though survey respondents consistently listed "more courteous drivers" as a factor which would encourage them to cycle more and the city should work on addressing this.
	weather	(Belon et al., 2014; Parkin et al., 2007a)	no	Assumed constant across entire problem area.
	On-road lanes vs Off-road paths	(Pucher et al., 2010)	no	accounted for by measured separation
	Parking and End-of-trip facilities	(Pucher et al., 2010)	no	These can be built after cycle lane is installed or by interested businesses.
	Accessibility of Infrastructure by certain groups	(Belon et al., 2014)	no	Assume public infrastructure is accessible to all.
	Maintenance level (presence of trash, debris, and graffiti in non-designated locations)	(Belon et al., 2014)	no	This was determined to be fluctuating with time and highly depended on the maintenance of the city work crews.
	Dominate activities and sports within the community	(Belon et al., 2014)	no	More applicable on larger scales and selecting routes on the basis of whom already cycles is not a part of city's strategic plan.
	Local policies	(Belon et al., 2014)	no	Covered in this thesis' introduction, but policy is assumed constant for the Test Area.

	overall stress of immediate environment	(Parkin et al., 2007b; Parkin et al., 2007a)	no	Too individualized for this study, more research will need to be conducted in the future to track cyclist's heart rate and stress levels as they cycle through routes.

Appendix B: Forms Given to Stakeholder Groups (both during the in-person focus groups and through online participation)

Criteria Ranking: Online Surveys Adults with Children Aged 10-17

This MSc project is looking at how you and other Christchurch residents value bicycle facilities which might be constructed by the city. As these are publicly funded projects and the facilities need to be designed to meet the needs of as many people as possible, feedback from everyone, no matter how much you yourself cycle, is important.

There are sixteen questions total. After the first few questions, you will be presented with a series of infrastructure characteristics which you will be asked to rank. Thank you for your involvement. If you have any inquiries about this survey, feel free to email a request to Amy Butler at: a.butler@student.utwente.nl

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Do you have children between the ages of 10-17?
____ Yes
____ No

Does one or several of your 10-17 aged children have a disability or condition which inhibits them from cycling?
____ Yes (Please Explain)
____ No

What is your child's main mode of transportation to school?
____ Car
____ Motorcycle / Scooter
____ Bus
____ Bicycle
____ Walk / Run
____ They do not travel for school.
____ Other (please state)

The following are groups of statements representing sub-criteria for a bicycle-friendly route. To the best of your ability, please rank the sub-criteria by how important you believe they are for your 10-17 aged children to have <u>while cycling to and from school</u>.

Criteria Group: Comfort
Assign one of these to each of the following statements.
1 = Less Important 2 = More Important

_____ Having un-fractured, even pavement
_____ Having a non-slip surface

How sure of this rank were you? Please put a percent below.
0% = Not Sure At All, They Seem Equally Important *100% = Very Sure*

______

Criteria Group: Road Capacity

Assign one of these to each of the following statements.
1 = Less Important *2 = More Important*

_____ Having less traffic volume, and hence more road space
_____ Having fewer trucks on the route

How sure of this rank were you? Please put a percent below.
0% = Not Sure At All, They Seem Equally Important *100% = Very Sure*

______

Criteria Group: Safety

Assign one of these to each of the following statements.
1 = Less Important *2 = Important* *3 = More Important*

_____ Having bicycle facilities which are clearly visible to the drivers
_____ Having intersections with less traffic volume and with slower traffic speeds
_____ Having intersections with bicycle facilities

How sure of this rank were you? Please put a percent below.
0% = Not Sure At All, They Seem Equally Important *100% = Very Sure*

______

Criteria Group: Directness & Efficiency

Assign one of these to each of the following statements.
1 = Less Important *2 = Important* *3 = More Important*

_____ Having a direct route with minimal km travelled
_____ Having a route with fewer right-hand turns
_____ Having a route with less time waiting at intersections

How sure of this rank were you? Please put a percent below.
0% = Not Sure At All, They Seem Equally Important *100% = Very Sure*

______

Criteria Group: Connectivity & Transit Cohesion

Assign one of these to each of the following statements.
1 = Less Important or 2 = More Important

_____ Having other streets which can connect your child to the route
_____ Having bus stops which can connect your child to the route

How sure of this rank were you? Please put a percent below.
0% = Not Sure At All, They Seem Equally Important *100% = Very Sure*

______

Criteria Group: Attractiveness

Assign one of these to each of the following statements.

1 = Less Important   2 = Important   3 = More Important

____ Having a route adjacent to outdoor art, parks, clean public areas, or urban green space

____ Having a route away from sources of noise and pollution (e.g. High Speed Highways)

____ Having a route with street lights

How sure of this rank were you? Please put a percent below.
0% = Not Sure At All, They Seem Equally Important   100% = Very Sure

______

Criteria Group: Demand

Assign one of these to each of the following statements.
1 = Less Important   2 = More Important

____ Having a route near your house

____ Having a route near destinations (e.g. your child's school, stores, your workplace)

How sure of this rank were you? Please put a percent below.
0% = Not Sure At All, They Seem Equally Important   100% = Very Sure

______

The following are groups of statements which represent main criteria of a bicycle-friendly route. To the best of your ability, please rank the main criteria by how important you believe they are for your 10-17 aged children to have while cycling to school.

Rank the following statements from 1-7, with: 1 = Less Important   7 = More Important

____ Having a **comfortable** route with un-fractured, even paving as well as a rough, non-slip surface

____ Having road capacity with less traffic volume and fewer trucks on the route

____ Having a safe route with bicycle facilities, higher visibility, less traffic volume and slower traffic speeds at intersections

____ Having a direct and efficient route with minimal detour and travel time delay

____ Having a well-connected and cohesive route which gives your child access to other streets and to the city's public transportation

____ Having an attractive route adjacent to parks, public areas, urban green space, and which has street lighting, and is away from noise and pollution

____ Having a route with good demand which is near your house and convenient to destinations

How sure of this rank were you? Please put a percent below.
0% = Not Sure At All, They Seem Equally Important   100% = Very Sure

______

Thank you for your personal ranking of the criteria, this will be included in the group ranking. The results of this survey will determine the weights which will be applied to each criterion, and the criterion's weight will determine how much influence it will have in the route assessment. The findings from this study will be given to the city of Christchurch to use at their discretion.

Appendix C: List of Comments from Stakeholder Analysis Sessions (Sources Include: Focus Group Discussion, Commuter Maps, Criteria Ranking Forms, and Personal Emails Sent to Researcher)

Comment Category	Comment Sub-category	ID	Commenter (Cycle Freq.)	Comment (written exactly as commenter)
Behavior	Cyclist Behavior	1	Kate Palmer (2-3 d/week)	"Bike route to school: Ideally any road should be safe for kids to ride to school. School/Home (trips) will be different routes for all children, and children like to have independence to go visit friends, etc. If there were more cyclists of all ages on the road I would be more comfortable with my children cycling."
Behavior	Cyclist Behavior	2	Kate Palmer (2-3 d/week)	"(My) 16 and 19 year old boys--are very clumsy and irresponsible. Careless of their own safety."
Behavior	Cyclist Behavior	3	Current (Cyclist) Commuters Group Discussion	Discussion: Cyclist behavior needs to improve, because many do not know the laws or ride unsafely, or make good cyclists give bad impressions to drivers. And drivers don't know what to expect from a cyclist.
Behavior	Cyclist Behavior	4	Current (Cyclist) Commuters Group Discussion	Single Comment: Cyclists sometimes use the wrong lane, or are cycling down the wrong direction.
Behavior	Cyclist Behavior	5	Current (Cyclist) Commuters Group Discussion	Discussion: Bikers need to be taught to take the lane, that they can and should be more assertive with claiming their road space.
Behavior	Cyclist Behavior	6	Current (Cyclist) Commuters Group Discussion	Discussion: There are bikers who go without bright clothes at night, making them hard to see.
Behavior	Cyclist Behavior	7	Current (Cyclist) Commuters Group Discussion	Discussion: It is important for bikers to be aware, and for them to hear. Wearing headphones doesn't help them know a car is overtaking them.
Behavior	Driver Behavior	8	Joel Sugrue (4 d/week)	"Bealey Ave Impatient Drivers"
Behavior	Driver Behavior	9	Edward Pilbrow (5 d/week)	"(Cars on Kotare St) can cut the gentle corner and get too close."
Behavior	Driver Behavior	10	Ben Taylor (5 d/week)	"Roundabout at top of Columbo Street--people coming down Dyers Pass Rd, turning left and not check bike lane is free"
Behavior	Driver Behavior	11	Claudia McFie (5 d/week)	"Pulling out of side streets (and supermarkets, car parks, and driveways) without looking"
Behavior	Driver Behavior	12	Claudia McFie (5 d/week)	"Turning left in front of cyclist travelling straight"
Behavior	Driver Behavior	13	Claudia McFie (5 d/week)	"(Ilam Rd between Memorial Ave & Aorangi Rd) Outside Burnside Primary School--drivers pulling in and out of carparks during school drop-offs"
Behavior	Driver Behavior	14	Kate Palmer (2-3 d/week)	"Bike lanes good, but main issue for cyclists is driver behavior. Divers need to be more careful and considerate. This only happens if there are lots of cyclists on the road and they are used to seeing them and accepting them as part of normal traffic."
Behavior	Driver Behavior	15	Meg Chrishe (6 d/week)	"However--very narrow & cars @ intersections don't look for cyclists (I got t-boned here)"
Behavior	Driver Behavior	16	Current (Cyclist) Commuters Group	Single Comment: Cyclists are often overtaken before junctions, creating a dangerous situation.

			Discussion	
Behavior	Driver Behavior	17	Current (Cyclist) Commuters Group Discussion	Discussion: 100% of focus group agreed they'd had problems with cars not giving way when they should.
Behavior	Driver Behavior	18	Current (Cyclist) Commuters Group Discussion	Discussion: There is a general lack of awareness in regards to cyclists. Car drivers simply do not think cyclists will be on the road.
Behavior	Driver Behavior	19	Current (Cyclist) Commuters Group Discussion	Discussion: Drivers often mis-judge cycling speed. Often believing the cyclists are going slower than they are, then the vehicle turns or create other dangerous situations.
Behavior	Driver Behavior	20	Current (Cyclist) Commuters Group Discussion	Discussion: Aggressive/non-considerate drivers, however the focus group recognizes most drivers are good and it is only a few who cause many problems.
Behavior	Driver Behavior	21	John Ascroft (3 d/week)	"Drivers do not always give way, even at give way areas."
Behavior	Driver Behavior	22	Current (Cyclist) Commuters Group Discussion	Discussion: There is a lack of familiarity with cyclists sharing the road with cyclists.
Behavior	Driver Behavior	23	Current (Cyclist) Commuters Group Discussion	Single Comment: Sometimes drivers are too considerate. Drivers changing their speed too much to try and make it safe for cyclists can hold up traffic and end up making the situation worse.
Behavior	Driver Behavior	24	Current (Cyclist) Commuters Group Discussion	Single Comment: There should be cycle lane sanctity. Right now there are some drivers who are inconsiderate and blatantly take a turn after they make eye contact with you and know you're there.
Behavior	Driver Behavior	25	Current (Cyclist) Commuters Group Discussion	Discussion: Cars do not always accept if cyclists take the lane at an intersection (sitting in the middle of the lane and taking up space as a car would), and they sometimes get very close to the cyclists or bump the bike's back tire with their bumper.
Behavior	Media/Public Perception/Initiatives	26	Current (Cyclist) Commuters Group Discussion	Single Comment: Media does not help to reduce the tension between cars and cyclists. The stories in the news only aggravate it.
Behavior	Media/Public Perception/Initiatives	27	Grace Ryan (4-5 d/week)	"Cyclists have a dehumanized image. This can improve if cyclists are more openly friendly and remind the drivers they are people too, through waving and other good behavior. Interacting and communicating are important."
Behavior	Media/Public Perception/Initiatives	28	Current (Cyclist) Commuters Group Discussion	Discussion: There was a very good billboard campaign recently which showed a picture of a cyclists and said something to the effect of "I'm a doctor, I'm a mother, etc." Improving these media promotions could really help reduce the tension and aggression between cyclists and drivers.
Behavior	Media/Public Perception/Initiatives	29	Grace Ryan (4-5 d/week)	"Cycling needs to get sexier" (in reference to increasing cycling's modal share).

Behavior	Media/Public Perception/Initiatives	30	Current (Cyclist) Commuters Group Discussion	Discussion: (Personal) Perceptions of safety improve once people start cycling themselves. And people are better able to see the direct benefits. There's environmental value, it can be just as fast for time, and cyclists save money from not buying petrol. How cycling seems to be less of a stop and start trip than what is typically experienced in a car. Cycling is a more continuous travel experience and involves less idling, but non-cyclists do not know this.
Behavior	Media/Public Perception/Initiatives	31	Current (Cyclist) Commuters Group Discussion	Discussion: While some cyclists want to be completely separated from traffic, others believe the more cyclists who are on the road and visible, the higher comfort all cyclists will feel in general and there will be a raised awareness to drivers.
Behavior	Media/Public Perception/Initiatives	32	Grace Ryan (4-5 d/week)	"There is a lack of funding for data collection, pro-cycling initiatives, and education of drivers."
Behavior	Media/Public Perception/Initiatives	33	Current (Cyclist) Commuters Group Discussion	Discussion: More penalties could be given for at-fault drivers. There needs to be legislature to lay down the policies and enforcement of the laws. It would help if the investigations of vehicle-bicycle crashes assumed the driver is at fault. Because right now the drivers claim the cyclists swerved, or it was only the cyclist's fault.
Behavior	Media/Public Perception/Initiatives	34	Glen Tregurtha (5 d/week)	"On the Driver's License Test, they should ask a question or two from the cyclist's perspective."
Behavior	Media/Public Perception/Initiatives	35	Current (Cyclist) Commuters Group Discussion	Discussion: There is an anti-cyclist sentiment. People tend to think, "all cyclists wear lycra", or "all cyclists run red lights".
Behavior	Media/Public Perception/Initiatives	36	Glen Tregurtha (5 d/week)	"Right now there is no easy way for people to offer advice on which areas or designs need infrastructure improvement. Nor can people easily report when the cycle lanes are in poor condition and need maintenance. There should be an app for people to give constructive, location-specific maintenance and infrastructure advice."
Behavior	Pedestrian Behavior	37	Current (Cyclist) Commuters Group Discussion	Single Comment: People sometimes cross between stationary traffic.
Behavior	Pedestrian Behavior	38	Current (Cyclist) Commuters Group Discussion	Single Comment: On the separated pedestrian and cycle paths in Hagley Park, pedestrians don't see the difference between the cycle path and the foot path, making cycling slow and with a lot of veering to avoid pedestrians.
Connectivity	Lack of Options	39	Shane Mac (1 d/month or "when can't find a ride"	"too many 1 line routes"
Connectivity	Lack of Options	40	Jason Motha (7 d/week)	"(Ilam Road) Not enough entry/exit points."

Connectivity	Lack of Options	41	Claudia McFie (5 d/week)	"Curletts Rd Detour to underpass for cycleway adds 4 km to journey (if following the official cycle route instead of just running across drainage ditch and the motorway). :(The only other alternative to cross railroad is via Annex Rd underpass--requires cycling down Annext/Birmingham Rd--industrial area with heavier vehicles."
Connectivity	Lack of Options	42	Claudia McFie (5 d/week)	"(There are) lots of 'radial' routes, less 'ring' routes."
Good Facilities	Cycle Lane Separation	43	Dan McKenzie (4 d/week)	"Ilam Rd --Love it"
Good Facilities	Cycle Lane Separation	44	Claudia McFie (5 d/week)	"Good intersection where (can't remember if Simeon or Selwyn St) cyclelane separated from traffic with reflective sticks"
Good Facilities	Cycle Lane Separation	45	Claudia McFie (5 d/week)	"Ilam Rd upgrade really good, esp. separated by kerb from traffic."
Good Facilities	Cycle Lane Separation	46	Current (Cyclist) Commuters Group Discussion	Discussion: The less confident cyclists of the focus group requested more off-road paths or grass/berm-separated lanes. These people said it was easier to share space with pedestrians than with cars.
Good Facilities	Cycle Lane Separation	47	Current (Cyclist) Commuters Group Discussion	Discussion: Raised barrier separated bicycle lanes are liked for their safety.
Good Facilities	Intersections	48	Shane Mac (1 d/month or "when can't find a ride"	"Good light here (near Denton Park)"
Good Facilities	Intersections	49	Edward Pilbrow (5 d/week)	"(Annex Rd) Underpass is good."
Good Facilities	Intersections	50	Edward Pilbrow (5 d/week)	"Cycle traffic light (Riccarton Rd into Hagley Park) is good"
Good Facilities	Intersections	51	Jason Motha (7 d/week)	"(Moorhouse Ave) This hook-turn facility is good, but cyclists and motorists don't know how to use/respect it"
Good Facilities	Intersections	52	Current (Cyclist) Commuters Group Discussion	Discussion: 90% of focus group claimed to like the reflective flexi-posts at intersections, as it protected the cycle lane and provided better visibility than simple paint or low, cement-separated barriers.
Good Facilities	Parked Cars	53	Jason Motha (7 d/week)	"(Moorhouse Ave) Car Door buffer zone a good thing."
Good Facilities	Parked Cars	54	Glen Tregurtha (5 d/week)	"(Ilam Rd) Space for opening car doors is good."
Good Facilities	Parked Cars	55	Meg Chrishe (6 d/week)	"Gassen is great, no parked cars, no threat of getting doored."
Good Facilities	Parked Cars	56	Current (Cyclist) Commuters Group Discussion	Discussion: 100% of focus group agreed there was insufficient space on many streets. That there was not room for parked car doors, bikes, and trucks. That when car doors swing out, the cyclist has to veer to avoid it and endanger themselves with traffic. The focus group agreed the "door space" painted on the road helped protect them from this.
Maintenance	Broken Glass	57	Tim Hate (5 d/w)	"In general too much broken glass in the cycle lanes/side of the road"

Maintenance	Broken Glass	58	Current (Cyclist) Commuters Group Discussion	Discussion: 100% of focus group agreed there was a problem with street cleaning. That often there is broken glass or debris in the cycle lanes and that sometimes things just get pushed from the roads and are stuck in the gutters, overflowing into the cycle lane.
Maintenance	Road Works	59	Kate Palmer (2-3 d/week)	"Ferrry Rd road works, uneven surfaces, road cones often placed so that cyclist is forced into single lane traffic."
Maintenance	Road Works	60	Tom Alton (4-5 d/week)	"Roadwork signs in cycle lane"
Maintenance	Road Works	61	Current (Cyclist) Commuters Group Discussion	Discussion: Changes to traffic controls (due to road works) forces drivers and cyclists to constantly re-assess where they should be in relation to one another, which regularly increases risk.
Maintenance	Road Works	62	Current (Cyclist) Commuters Group Discussion	Single Comment: The way road works are set up have no consideration for cyclists.
Navigation	General Road Segment Difficulty/Danger	63	Dan McKenzie (4 d/week)	"Glandovey Rd between Garreg Rd and Bryndwr Rd Bad"
Navigation	General Road Segment Difficulty/Danger	64	Andy Beale (5 d/week)	"Avoid 3 roads: Riccarton Rd, Sparks Rd, and Birmingham Dr (between Print Pl & Wrights Rd Roundabout)"
Navigation	General Road Segment Difficulty/Danger	65	Glen Tregurtha (5 d/week)	"Bridge too narrow so cars cut you off (where Harper Ave enters Hagley Park)"
Navigation	General Road Segment Difficulty/Danger	66	John Ascroft (3 d/week)	"(Wairakei Rd between Russley Rd & Wooldridge Rd) No cycle lane, lots of traffic, cars parked all along."
Navigation	General Road Segment Difficulty/Danger	67	Meg Chrishe (6 d/week)	"Coming home I come down Burbadoes. I always feel safer on Bubadoes than on Madras. In fact the commute home feels much safer than the commute to work. Getting off Walthon (right turn) into Riverlew can be tricky sometimes"
Navigation	General Road Segment Difficulty/Danger	68	Current (Cyclist) Commuters Group Discussion	Single Comment: Bumpy Surfaces
Navigation	Lane Change Difficulty	69	Gareth Wright (unknown)	"Difficult to Change Lanes to head down Yaldhurst"
Navigation	Lane Change Difficulty	70	Greg Bassam (unknown)	"Crossing multiple lanes (on Colombo St south of Gloucester St)"
Navigation	Lane Change Difficulty	71	Grace Ryan (4-5 d/week)	"Getting across two busy lanes to make RT (on Riccarton Rd between Yaldhurst Rd & Hansons Ln)."
Navigation	Left-turn Difficulty/Danger	72	Gareth Wright (unknown)	"Left turn lane (green arrow merge) into Hansons--no refuge for straight-ahead cyclists"
Navigation	Left-turn Difficulty/Danger	73	Dan McKenzie (4 d/week)	"Wharenui Rd - Reverel St/Lochee Bad"
Navigation	Left-turn Difficulty/Danger	74	Edward Pilbrow (5 d/week)	"There should be a gap (on Harewood Rd) in the footpath for bikes to turn left (onto Wooldridge Rd) at any time."
Navigation	Right-turn Difficulty/Danger	75	Tim Hate (5 d/week)	"Intersection at Coronation St & Whiteleigh Rd is extremely dangerous to turn"

Navigation	Right-turn Difficulty/Danger	76	Dan McKenzie (4 d/week)	"Wharenui Rd - Reverel St/Lochee Bad"
Navigation	Right-turn Difficulty/Danger	77	Tom Alton (4-5 d/week)	"(Different Route) for return commute because too hard to to get off (Brougham St and get onto Selwyn St)"
Navigation	Right-turn Difficulty/Danger	78	Tom Alton (4-5 d/week)	"Hard to turn right onto Lyttleton/Wrights Rd from cycle path (while heading NW on Brougham St) in mornings as hard to find gaps in traffic."
Navigation	Right-turn Difficulty/Danger	79	Glen Tregurtha (5 d/week)	"Difficult turning right here (from Bealey Ave to Papanui Rd), having to cross several lanes."
Navigation	Right-turn Difficulty/Danger	80	Greg Bassam (unknown)	"Turning right (from Main North Rd) onto Sawyers Arms Rd"
Navigation	Right-turn Difficulty/Danger	81	Greg Bassam (unknown)	"Turning right to go (from Main North Road) onto Cranford St at the light/intersection"
Navigation	Right-turn Difficulty/Danger	82	Kate Palmer (2-3 d/week)	"Ensors/Ferry Rd intersection, multi-lane, right turn difficult as no cycle lane provision."
Navigation	Right-turn Difficulty/Danger	83	Grace Ryan (4-5 d/week)	"This is dodgy--Crossing Yaldhurst Rd (on my way home heading northwest) between Avonhead Rd & Brodie St"
Navigation	Right-turn Difficulty/Danger	84	Grace Ryan (4-5 d/week)	"Crossing Annex Rd from shared (cyclist/footpath) lane to LHS of Annex Rd"
Navigation	Right-turn Difficulty/Danger	85	John Ascroft (3 d/week)	"Dislike the right turns on Memorial Lane"
Navigation	Right-turn Difficulty/Danger	86	Meg Chrishe (6 d/week)	"I have to turn right off Tenneyson St--very diff to find a gap thru traffic, get over culvert & not hold up other cyclists"
Navigation	Right-turn Difficulty/Danger	87	Current (Cyclist) Commuters Group Discussion	Discussion: Right turns at intersections are generally dangerous as the cyclists are competing directly with cars.
Navigation	Roundabout Difficulty/Danger	88	Tom Alton (4-5 d/week)	"(Wrights Rd) This roundabout is quite hard since it went to two lanes. Sometimes feels dangerous."
Navigation	Roundabout Difficulty/Danger	89	Andy Beale (5 d/week)	"Avoid 2 roundabouts: Main South Road/Blenheim, and Russley Rd/Memorial Ave"
Navigation	Roundabout Difficulty/Danger	90	Jason Motha (7 d/week)	"Exiting the bridge (from Main South Rd and entering Blenheim Roundabout) have to cross a lane of traffic, then cross in front of traffic at a give way sign before entering the roundabout"
Navigation	Roundabout Difficulty/Danger	91	Glen Tregurtha (5 d/week)	"Dangerous Roundabouts multi lanes (Blenheim & Main South Rd, Riccarton Ave & Deans Ave)"
Navigation	Roundabout Difficulty/Danger	92	Don Babe (5 d/week)	"Sockburn (with Blenheim & Main South Road) roundabout--not friendly"
Navigation	Roundabout Difficulty/Danger	93	Don Babe (5 d/week)	"Southern motorway roundabout is suicide"
Navigation	Through Intersection Difficulty/Danger	94	Dan McKenzie (4 d/week)	"Riccarton Rd - Middleton Rd/Ilam Rd Difficult"
Navigation	Through Intersection Difficulty/Danger	95	Dan McKenzie (4 d/week)	"Lincoln Rd - Lyttleton St Difficult"
Navigation	Through Intersection Difficulty/Danger	96	Tom Alton (4-5 d/week)	"(Intersection of Brougham St & Lincoln Rd) Hard crossing Lincoln Rd when on cycle path next to motorway in mornings because often no gap in traffic."
Navigation	Through Intersection Difficulty/Danger	97	Jason Motha (7 d/week)	"Have to give way halfway through the intersection (from Memorial Ave going into Hagley Park)"

Navigation	Through Intersection Difficulty/Danger	98	Jason Motha (7 d/week)	"(Cars and Trucks) quite often right turn (from Main South Road onto Watts Rd) and block the lane."
Navigation	Through Intersection Difficulty/Danger	99	Glen Tregurtha (5 d/week)	"Often get cut off here by cars turning left (from Papanui) onto Harewood Rd."
Navigation	Through Intersection Difficulty/Danger	100	Grace Ryan (4-5 d/week)	"Dodgy--Annex Road crossing the rail tracks"
Navigation	Through Intersection Difficulty/Danger	101	Shannon Boorer (2-3 d/week)	"Annex/Birmingham is horrible for cyclists!"
Navigation	Through Intersection Difficulty/Danger	102	Meg Chrishe (6 d/week)	"Crossing Brougham to Gasson. Cars routinely track into the cycle lane @ Brougham. Maybe a few rumble strips would remind them."
Navigation	Through Intersection Difficulty/Danger	103	Current (Cyclist) Commuters Group Discussion	Single Comment: Left-turning motorists don't think to leave sufficient space (and there is often no physical barrier to remind them) between them and the parked cars, making it difficult for cyclists to move through intersection.
Obstruction/ Visibility	Parked Cars	104	Shane Mac (1 d/month or "when can't find a ride"	"Too many park cars (on Yaldhurst, west of Racecourse Rd)"
Obstruction/ Visibility	Parked Cars	105	Shane Mac (1 d/month or "when can't find a ride"	"Car doors open at 3pm"
Obstruction/ Visibility	Parked Cars	106	Shane Mac (1 d/month or "when can't find a ride"	"Too many parked cars (on Moorhouse Ave, east of Colombo Street)"
Obstruction/ Visibility	Parked Cars	107	Edward Pilbrow (5 d/week)	"Cars park here and can't see when they back out." (On Roydvale Ave south of Memorial Ave; on Wooldridge Rd north of Wairakei Rd; on Avonhead Rd between Roydvale Ave & Withells Rd)
Obstruction/ Visibility	Parked Cars	108	Edward Pilbrow (5 d/week)	"Cars backing out from on sports ground and they can't see until they are mostly out."
Obstruction/ Visibility	Parked Cars	109	Current (Cyclist) Commuters Group Discussion	Discussion: 90% of focus group said they'd had problems with cars parked in the median.
Obstruction/ Visibility	Parked Cars	110	Current (Cyclist) Commuters Group Discussion	Discussion: 100% of the focus group members agree all on-road parking needs to allow space for the opening of car doors.
Poor Facilities	Designed Cycleways around Car Parks/Bus Stops	111	Jason Motha (7 d/week)	"(Ilam Road) Not that great to have cyclists go around the bus stops"
Poor Facilities	Designed Cycleways around Car Parks/Bus Stops	112	Glen Tregurtha (5 d/week)	"(on Papanui Rd) Outside the school with cycle lane veering around parked cars."
Poor Facilities	Designed Cycleways around Car Parks/Bus Stops	113	Glen Tregurtha (5 d/week)	"(Ilam Rd) Having to ride up onto the path to go behind the bus stops."
Poor Facilities	Disjoint Segment Cycle Lanes	114	Tom Alton (4-5 d/week)	"Make cycle lane down Brougham St continuous or not existing at all."
Poor Facilities	Disjoint Segment Cycle Lanes	115	Current (Cyclist) Commuters Group Discussion	Discussion: There is inconsistency with how the cycle lanes are designed and constructed. Many of them stop unexpectedly, leaving nowhere to go but merge with cars.

Poor Facilities	Major Cycleways Too Narrow	116	Joel Sugrue (4 d/week)	"Hagley Park: Must cycle in the park as the roads (Harper Ave and Dean Ave) are too narrow and dangerous. The park trails are narrow too and has heavy pedestrian traffic."
Poor Facilities	Major Cycleways Too Narrow	117	Jason Motha (7 d/week)	"(Ilam Road) Slow stack behind other cyclists. Can't overtake. Not wide enough. Some of the 'chicanes' are unsafe to take at speeds above 30 km/h. Very bumpy. Not enough space to avoid hazards such as broken glass."
Poor Facilities	Major Cycleways Too Narrow	118	Jason Motha (7 d/week)	"Cycle lane gets narrow with blind corners with pedestrian obstacles. (Moorhouse Ave/Blenheim Rd"
Poor Facilities	Major Cycleways Too Narrow	119	Glen Tregurtha (5 d/week)	"Cycle lane outside Macpac narrows to only 30 cm…" (on Blenheim Rd near intersection with Mandeville St)
Poor Facilities	No Cycle Facilities	120	Joel Sugrue (4 d/week)	"Bealey Ave has 3 lanes, but nothing for cycling"
Poor Facilities	No Cycle Facilities	121	Joel Sugrue (4 d/week)	"Corner of Bealey Ave and Park Terrace: no cycle lane, bikes forced onto the footpath."
Poor Facilities	No Cycle Facilities	122	Jason Motha (7 d/week)	"(Entering Main South Road to cross rail tracks) Coming from south no cycle lane at start of bridge, motorists often block the entrance (to the shared footpath)."
Poor Facilities	No Cycle Facilities	123	Shannon Boorer (2-3 d/week)	"Awful! No bike lane or shoulder on parts of Halswell Junction Rd & Springs Rd"
Poor Facilities	No Cycle Facilities	124	Shannon Boorer (2-3 d/week)	"Really small gap with no bike lane or shoulder & high speed traffic. Unsafe with lots of potholes on edge of road."
Poor Facilities	No Cycle Facilities	125	Shannon Boorer (2-3 d/week)	"Small off-road track that has been formed by cyclists--not sealed and overgrown. (Near Treffers Rd corner) could easily be formalised."
Poor Facilities	No Cycle Facilities	126	Current (Cyclist) Commuters Group Discussion	Discussion: There are junctions missing complete Advance Stop Boxes which could sorely use them and those junctions which do have them are often an incomplete design/construction.
Poor Facilities	No Cycle Facilities	127	Current (Cyclist) Commuters Group Discussion	Discussion: There is too little cycling infrastructure.
Poor Facilities	Shared Cycle Lane/ Footpath	128	Jason Motha (7 d/week)	"Cycle Lane goes up (raised at least a meter above the road pavement). It's bumpy, and you can't see driveway traffic, not wide enough. (Intermittent design along Lincoln Rd)"
Poor Facilities	Shared Cycle Lane/ Footpath	129	Jason Motha (7 d/week)	"(Moorhouse Ave) Shared with pedestrian cycleways, pedestrians seem to use all the path."
Poor Facilities	Shared Cycle Lane/ Footpath	130	Glen Tregurtha (5 d/week)	"Non-shared cycleways would be nice in Hagley Park. ie. Dedicated cycleways in the park"
Poor Facilities	Shared Cycle Lane/ Footpath	131	Glen Tregurtha (5 d/week)	"(Ilam Rd) Cycleway too narrow with not enough entry and exit points. No Space to pass or ride two abreast."
Poor Facilities	Shared Cycle Lane/ Footpath	132	Shannon Boorer (2-3 d/week)	"Gap in cycle network (between Canterbury Park & Birmingham Dr). Will eventually be fixed but in meantime, let's cyclists share the footpath (not many peds). Confusing at the moment--unsure if cyclists are allowed on the footpath."
Poor Facilities	Shared Cycle Lane/ Footpath	133	Current (Cyclist) Commuters Group	Discussion: There are many poorly designed separated lanes and paths which are meant to be shared with pedestrians, but there is not enough

			Discussion	room to accommodate all the activity/volume.
Poor Facilities	Transfer Between Segment Cycle Facilities & Junctions With None	134	Tom Alton (4-5 d/week)	"Bike path on Tennyson St is good, but nasty when coming back onto road (in order) to cross junctions."
Poor Facilities	Transfer Between Segment Cycle Facilities & Junctions With None	135	Greg Bassam (unknown)	"Having to cross under barrier (when getting from Hagley Park cycleway/footpath to Deans Ave)"
Poor Facilities	Transfer Between Segment Cycle Facilities & Junctions With None	136	Kate Palmer (2-3 d/week)	"Ferrymead Bridge (heading east), cycle route requires cyclists turning into Bridle Path Rd to cross at right-angle into fast moving traffic. Very Tricky and Dangerous. No light or turning lane for cyclists."
Poor Facilities	Transfer Between Segment Cycle Facilities & Junctions With None	137	Current (Cyclist) Commuters Group Discussion	Discussion: Dislike of Advanced Stop Boxes (ASBs), as cars are usually pulled up too far and taking space of the ASB. Often there is an ASB at a junction, but no lanes/room for cyclists to move up to them, and some drivers don't understand this is what the cyclist is legally allowed to do and they think they are being rude or cutting the line. This misunderstanding leads to aggression aimed at the cyclist and occasionally cyclists receive threats from drivers for using ASBs properly.
Poor Facilities	Unclear Design	138	Jason Motha (7 d/week)	"(Moorhouse Ave) Inconsistency of Cycle Lane Color"
Poor Facilities	Unclear Design	139	Jason Motha (7 d/week)	"(Near intersection of Halswell Rd/Curletts Rd/Hoon Hay Rd) Cycle lane ends up on the wrong side of the road with no obvious way to go."
Poor Facilities	Unclear Design	140	Glen Tregurtha (5 d/week)	"What colour are cycleways? Choose one colour and make it standard across the city. Please. The same goes for all other conventions--hook turns? Style of cycle lanes? Various systems in use at traffic lights. Confusing."
Poor Facilities	Unclear Design	141	Claudia McFie (5 d/week)	"Cycleway crossing (the railroad) Harewood Rd gets a bit 'lost' unless you know where to rejoin it."
Poor Facilities	Unclear Design	142	Shannon Boorer (2-3 d/week)	"CSM (along the Southern Motorway) needs better cycle signage. People get lost. Nice Track though."
Poor Facilities	Unclear Design	143	Current (Cyclist) Commuters Group Discussion	Discussion: 100% of focus group agreed there was confusion on what to do when turning at a traffic light and design needs to be improved and more information given to road users.
Poor Facilities	Unclear Design	144	Current (Cyclist) Commuters Group Discussion	Discussion: Poor traffic control at intersections as the lanes are often confusing.
Poor Facilities	Unclear Design	145	Current (Cyclist) Commuters Group Discussion	Discussion: There needs to be more signage about sharing the road.

Poor Facilities	Unclear Design	146	Current (Cyclist) Commuters Group Discussion	Single Comment: When there is traffic on a busy road, it is seen as polite for drivers to stop before a 3-way junction, thus allowing cars to still get in and out of the connecting road. However, the turning car doesn't know there is are cyclists coming up and he may just go. Sometimes the polite driver who stopped even waves the car forward, signaling all clear without first checking for cyclists. This creates many near-collision situations. Design could improve the cyclists' visibility.
Traffic Related	Bus Conflict	147	Shane Mac (1 d/month or "when can't find a ride"	"Buses on the same route will make it worse"
Traffic Related	Bus Conflict	148	Andy Beale (5 d/week)	"Problems with Bus Lane on Main North Road"
Traffic Related	Bus Conflict	149	Current (Cyclist) Commuters Group Discussion	Discussion: There is inconsistency with cycleways and busses, and often the buses end up cutting off the cycle lane when they make a stop.
Traffic Related	Bus Conflict	150	Current (Cyclist) Commuters Group Discussion	Discussion: The current bus stops are not wide or deep enough for the bus to fully pull in and not block portions of the road. Widening and deepening the bus stops would help, and adding extra mirrors (the big ones to be placed on the side of the road) could help bus drivers see if there's an upcoming cyclists.
Traffic Related	Congestion Blocks Junction Cycle Lane	151	Tim Hate (5 d/week)	"Intersection at Riccarton Rd/Clyde Rd is too congested at peak hours/cars block cycle lane when turning left off Clyde Rd…cars are using the cycling lane as teeming lane, blocking it"
Traffic Related	Congestion Blocks Junction Cycle Lane	152	Kate Palmer (2-3 d/week)	"Traffic Lights can be a 'choke point' when cars queuing & less width for traffic to pass cyclists."
Traffic Related	Road is too Busy	153	Shane Mac (1 d/month or "when can't find a ride"	"Too busy" (Hagley Park/Riccarton to Arthurs Pass)
Traffic Related	Road is too Busy	154	Edward Pilbrow (5 d/week)	"Volume" (is a problem to cycle with)
Traffic Related	Truck Conflict	155	Tom Alton (4-5 d/week)	"(Brougham St East Bound--76 Motorway) Really scary when parked cars are occupying 'hard shoulder' as (cyclists) often have to 'compete' with large trucks."
Traffic Related	Truck Conflict	156	Shannon Boorer (2-3 d/week)	"Gap in cycle network (between Canterbury Park & Birmingham Dr). Very dangerous with lots of trucks."