DELIVERING EFFECTIVE CYCLE FACILITIES: MODELLING BICYCLE ROUTE CHOICE IN NEW ZEALAND

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ABSTRACT

Travel forecasting models that incorporate cycling often make the assumption that cyclists choose the minimum distance route between origins and destinations, travelling at a constant speed and without considering network attributes. However, studies have shown that in reality half of all cycle trips are over ten percent longer than the calculated shortest path.

This paper reviews a number of international Level of Service (LOS) calculations and cycling route choice methodologies, including the data requirements in developing and applying such models in a GIS environment. Results of the literature review are used to develop a cyclist route choice model for New Zealand, which has been incorporated into the Hamilton city accessibility model, currently being developed for the Hamilton City Council by Abley Transportation Consultants Limited.

The research presents the Abley Cycle Route-Choice Metric (ACRM), which is a significant improvement to previous methods of cyclist route choice modelling in New Zealand. The ACRM exhibits a high level of similarity with NZTA Economic Evaluation Manual values, however, it is defined over a much wider range of roadway variables for segments, and also represents cyclist avoidance preferences for intersection types by movement type, control scheme and vehicle volumes.

This presentation will interest people seeking better ways to identify smarter inter- and intra-network connections, and will assist in identifying the real costs and benefits of proposed transport infrastructure projects that impact upon cyclists.

INTRODUCTION

The majority of travel forecasting models that incorporate cycling make the assumption that cyclists choose the minimum distance route between origins and destinations, travelling at a constant speed and without favouring any particular type of facility. However, studies have shown that in reality half of all cycle trips are over ten percent longer than the calculated shortest path (Broach, Gliebe and Dill 2011). Adequately modelling cyclist route choices enables smarter inter- and intra-network connections to be identified, and highlights the real costs and benefits of transport infrastructure projects.

This research proposes an improvement to the method of calculating cyclist routes that takes the preferences of cyclists into account. The work has been undertaken as part of the Hamilton city accessibility model, currently being developed for the Hamilton City Council by Abley Transportation Consultants Limited. Identifying the transport disadvantaged and better understanding active modes are important goals for the Hamilton City Council; the cycle network route choice enhancements resulting from this research will contribute significantly to furthering these objectives.

LITERATURE REVIEW

A number studies were identified that had the potential to inform development of the improved route choice model. These studies fall into two broad categories:

1. **Level of Service (LOS):** a qualitative analysis of roadway design elements which uses a series of criteria to produce a ‘mode-friendliness’ score for a given road segment. Usually based upon data from stated preference (SP) survey responses, or simply assumed.
2. **Route choice models:** quantitative models that are usually based upon revealed preference (RP) data that has been mathematically and spatially analysed.

This section of the report analyses a number of studies that fall into the above categories; it critically examines the applicability to New Zealand, and considers the data requirements of implementing this type of model in a New Zealand context. For the purposes of this report the term *bike lane* refers to any on-street painted cycle facility, while *bike path* refers to off-street/separated cycle facilities.

Bicycle and Pedestrian Level of Service: Gainesville, Florida

As part of the Gainesville Mobility Plan Prototype, Dixon (1996) generated a LOS performance-measure point-system for rating the bicycle LOS of road segments (not intersections). This method has a similar format to many LOS calculation schemes, and is shown in **Table 1**. Scores output from the point system are assigned a LOS value, from A to F, by the process outlined in **Table 2**. The analysis was drawn from research performed by Epperson (1994) as well as other research and the specific needs of the Gainesville Mobility Plan. Applying this model in a GIS context would require attributes for all the variables listed in Table 1, and a method for converting the LOS value into a quantitative attribute applicable to link travel times.

Table 1. Bicycle Level of Service performance-measure point-system (Dixon 1996)

Category	Criterion	Points
Bicycle facility provided	Outside lane 3.66m	0
	Outside lane > 3.66m-4.27m	5
	Outside lane > 4.27m	6
(Max Value = 10)	Off-street/Parallel alternative facility	4
Conflicts	Driveways & side streets	1
	Barrier free	0.5
	No on-street parking	1
	Medians present	0.5
	Unrestricted sight distance	0.5
(Max Value = 4)	Intersection implementation	0.5
Speed differential	> 48 km/hr	0
	40 – 48 km/hr	1
(Max Value = 2)	24 – 32 km/hr	2
Motor vehicle LOS	LOS = E, F, or 6 or more travel lanes	0
	LOS = D and < 6 travel lanes	1
(Max Value = 2)	LOS = A, B, C, and < 6 travel lanes	2
Maintenance	Major or frequent problems	-1
	Minor or infrequent problems	0
(Max Value = 2)	No problems	2
TDM/Multi-modal	No support	0
(Max Value = 1)	Support exists	1

Calculation: Segment score = sum of points
Segment weight = Segment length / Corridor length
Adjusted segment score = Segment score x Segment weight
Corridor score = sum of Adjusted segment scores in the corridor

Table 2. Cyclist Level of Service definitions and comments (Dixon 1996)

Score	LOS	Comments
17 < score ≤ 21	A	Safe, attractive, children – few vehicles
14 < score ≤ 17	B	Adequate
11 < score ≤ 14	C	On-street
7 < score ≤ 11	D	Vehicle interaction med-high, keen riders only
3 < score ≤ 7	E	Vehicle interaction high; only keen riders
score ≤ 3	F	Cyclists at high level of risk

Bicycle Compatibility Index (BCI): U.S.A.

With the intention of creating a methodology that might be widely accepted by engineers, planners and bicycle coordinators in determining the compatibility of a roadway for both cyclists and motor vehicles, Harkey, Reinfurt and Knuiman (1998) developed the BCI. A video survey was conducted showing clips from 67 separate sites with varying geometric and operational characteristics; there were 202 participants in total from three different American cities. This SP survey gathered respondent answers in the form of a five point *bicycle stress level*. The study identified that bicycle lane presence and width, vehicle lane width, volume and speed, parking, roadside development type, truck and right turn volumes, and parking turnover all significantly influenced cyclist stress. The model developed by this research calculates a BCI value for roadway segments (not intersections), taking the all the significant variables identified above as inputs.

The BCI method has been applied to New Zealand in the multi-modal wide-area transportation simulation model of Hastings and Havelock North (Bargh and Kelly 2011). The assignment aspect of the cycle model developed by this work utilised a geodatabase to provide an indication of the relative attractiveness (or deterrence) of each route through the Hastings road network from the perspective of a cyclist. The BCI was used to provide these link cost factors. A partial validation was carried out, to confirm that general trends predicted by the BCI model were correct, but the BCI equation coefficients were not calibrated in a New Zealand context.

Pedestrian and Bicycle LOS on Roadway Segments: Denmark

The Danish Road Directorate sponsored a study to develop methods for objectively quantifying pedestrian and bicyclist stated satisfaction with road sections between intersections (Jensen 2007). This SP study, in which 407 participants were shown video clips taken by pedestrians and cyclists on 56 road segments, found that motorised traffic volume and speed, land uses, width of facilities, number and width of vehicle lanes, volumes of pedestrians, cyclists and parked cars, and presence of median, trees and bus stops all significantly influence the level of satisfaction. Logit models for walking and cycling were created to calculate the satisfaction level dependent upon a variety of inputs; examples of the outputs are shown in **Figure 1**. The study also generated a set of Microsoft Office EXCEL spreadsheets allowing practitioners to quickly evaluate LOS for existing or proposed facilities. The researchers compared the outputs of this model to a number of American LOS models, and found that there were similarities between trends, but the Danish model placed a higher importance upon the presence of pedestrian and bicycle facilities, presumably as these are more expected by cyclists in Denmark than America.

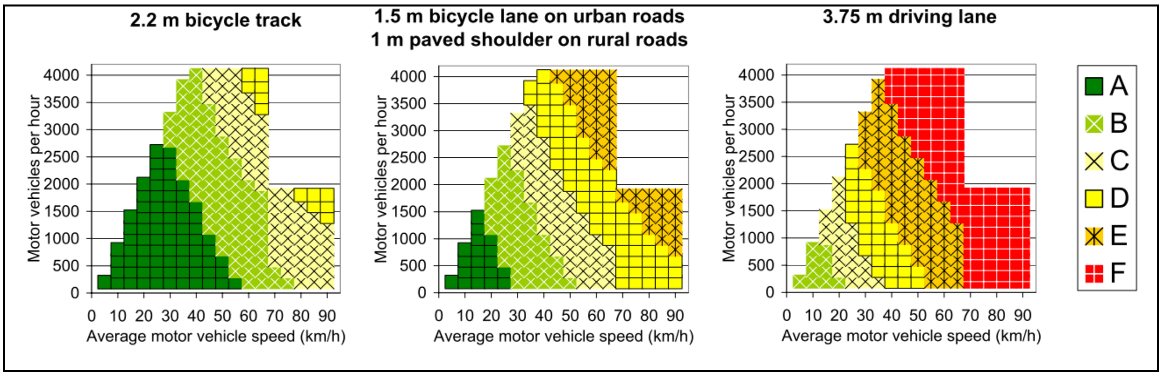

Figure 1. Level of Service results for three types of bicycle facilities (Jensen 2007)

Multimodal Level of Service (MMLOS): U.S.A.

The National Cooperative Highway Research Program (NCHRP) developed and calibrated a method for evaluating the MMLOS provided by different urban street designs and operations (NHCRP 2008). The study first analysed existing American methodologies, the Highway Capacity Manual (HCM) and the Florida Department of Transport Quality/Level of Service (FDOT Q/LOS) handbook, then critically compared these methods against the goals of the NCHRP project. The study identified that both methods treated different modes inconsistently, and as a result didn't adequately allow multimodal comparisons to be undertaken. The NCHRP developed a video lab SP method for gathering traveller quality of service ratings; tests were undertaken in a variety of cities across America with a total of 145 participants. The results produced cycle LOS models for segments and intersections, and found number of lanes, motor vehicle volume and speed, number of heavy vehicles, pavement surface condition, parking occupancy and widths of cycle facilities and near vehicle lanes as significant variables for segments; while width, crossing distance, motorised traffic volume and number of lanes were significant variables for intersections.

Economic Evaluation Manual: New Zealand

The New Zealand Transport Agency (NZTA) Economic Evaluation Manual contains values for the *benefit factors*, in terms of a *relative attractiveness*, of different cycle facility types, as outlined in **Table 3** (NZTA 2010). These values were identified by an SP survey to determine the additional time that cyclists would spend travelling on three alternative types of facility compared to 20 minutes of travel in-traffic with road-side parking. Intersections were not included in the analysis.

Table 3. Economic Evaluation Manual values of relative facility attractiveness (NZTA 2010)

Type of cycle facility	Relative Attractiveness
On-street with parking, no marked cycle lane	1.0
On-street with parking, marked cycle lane	1.8
On-street without parking, marked cycle lane	1.9
Off-street cycle path	2.0

Bicycle Route Choice Model: Portland, Oregon

In response to growing policy-maker interest in active transport modes and healthier lifestyles, this study utilised global positioning system (GPS) devices to collect RP data of actual cyclist routes in Portland, Oregon (Broach, Gliebe and Dill 2011). In total, 164 cyclists carried devices for several days, resulting in 1,449 non-exercise trips available for analysis. The trips were analysed in a Geographic Information Systems (GIS) database of the existing cycle network including facility types, bike lanes and off-road trails. For each trip, a set of alternative routes were generated, with a median of 20 possible alternative routes generated for each trip. A Path-Size Logit approach was used to overcome the overlapping routes problem. Some of the research findings were:

1. Travel times were highly correlated with distance (r = 0.93) such that the two were more or less interchangeable
2. Half of all observed trips were less than 10 percent longer than the shortest path, and 95 percent of trips were less than 50 percent longer

The model was used to develop a series of relative distance values for variables that were found to be significant: trip type (commute or non-commute), slope, intersections (by signal and turn type, and motor vehicle volumes), cycle facility type and motor vehicle volume on roads without cycle facilities. The route choice model developed by this research is being implemented as part of the Portland regional travel forecasting system.

Bicycle Route Choice Data Collection: San Francisco, California

The San Francisco County Transportation Authority utilised the capability of GPS-enabled smart phones to collect RP data on cyclist route choices in San Francisco, and performed analysis similar to that carried out in the Portland research (Charlton, Sall, Schwartz and Hood 2011; Hood, Sall and Charlton 2011). Findings were similar to those of the Portland research, with turns, cycling against traffic, cycle facilities and slope all identified as significant; although this analysis did not include intersections. The route choice model developed by this research is currently being integrated into the San Francisco regional travel model.

DISCUSSION OF EXISTING METHODOLOGIES

Inputs and outputs for each of the methodologies reviewed in the previous sections are summarised in **Table 4**. To be applicable in developing a New Zealand route choice model, inputs must be available within a GIS environment and the output must have the potential to be converted into a meaningful and verifiable route attribute.

The majority of the methods reviewed in this paper are LOS calculations, designed to assess proposed roadway developments or specific routes within existing networks. All of these studies were derived using stated preference (SP) surveys, where participants provide comfort, stress or quality of service ratings after viewing pictures or videos filmed along selected 'indicative' sites. Models for predicting the comfort, stress or quality are then developed by comparing the responses against a wide variety of measured or estimated variables for each site. Scores output by the models are then converted to LOS ratings by qualitative partitioning.

However, there are three issues precluding the use of LOS studies for this work:

1. Although SP surveys are easier to conduct and results can be analysed more readily, their application to analysing cyclist route choices presents a number of drawbacks. Most notably: the disconnect between picture/video displays and real experiences, participants using their own usual routes as points of comparison, strategic bias, and the fact that people often do not do what they say they would do (Broach, Gliebe and Dill 2011; NZTA 2010).
2. Calculation of an LOS score typically requires a large amount of detailed information for each road segment and intersection, as shown in Table 1. This information, although available when a roadway segment is being designed, is not typically available in a GIS format after project completion, nor at the regional level.
3. The method for converting an LOS score to an effective travel time is unclear, and would not be easily verifiable.

RP studies collect real data of what people actually did and then perform mathematical analysis upon these results to derive explanatory models. In this application, purely by their nature, RP studies are built upon available GIS data. Due to the issues outlined above, the two RP studies, either Portland or San Francisco, are preferred over the SP survey derived LOS studies. Of these two studies, the Portland model is sensitive to a wider range of variables and includes intersections. It is therefore selected as the basis for the New Zealand cycle route choice model developed by this research. The cyclist route analysis carried out in Portland produced relative distance values, indicating the extra distance a cyclist would be willing to travel on one type of facility to avoid another. These values are presented in the research as distance trade-offs; however, as the Portland researchers found that distance and time are practically interchangeable, they have been converted to time scaling factors for display in **Table 5**. The values have been arranged such that a bike lane receives a scaling factor of one. The results indicate that, in Portland, a commuting rider would rather cycle approximately eight times longer on a bike lane than they would on a road with no cycle facility and more than 30,000 vehicles per day (vpd). Intersection delays were presented as percent increase in distance that would be preferable to increasing the number of intersections per mile by one; assuming a cyclist speed of 20 km/h (Austroads 2011) these values are presented as effective time delays in **Table 6**.

Table 4. Review of inputs and outputs for existing methodologies

			Florida	BCI	Denmark	MMLOS	EEM	Portland	San Francisco
Trip Type	Commute/non-commute							✓	
Includes intersections						✓		✓	
Bicycle Facility	Presence			✓			✓	✓	✓
	Off-road path		✓				✓	✓	✓
	Width		✓	✓	✓	✓			
	Buffer size				✓				
	Sight distance		✓						
	Slope							✓	✓
Conflicts	Parking	Presence	✓	✓			✓		
		Density				✓			
		Parking turnover rate		✓	✓				
	Roadway characteristics	Vehicle lane widths		✓	✓	✓			
		Number of vehicle lanes				✓			
		Medians present	✓						
	Vehicles	PV speed or differential	✓	✓	✓	✓			
		Motor vehicle volumes		✓	✓	✓		✓	
		Heavy vehicle volumes		✓		✓			
		Motor vehicle LOS	✓			✓			
	Intersections	Intersection type/density	✓			✓		✓	✓
		Intersection implementation	✓						
		Crossing turn volumes		✓				✓	
		Turn type, motor vehicles per				✓		✓	
	Other modes	Pedestrian activity			✓	✓			
		Bus stops			✓				
		TDM/Multi-modal support	✓						
	Other	Presence of trees/median			✓				
Maintenance	Issue severity/frequency, pavement condition		✓			✓			
Area Type	Residential			✓	✓				
	Non-residential			✓					
	Shopping				✓				
	Mixed				✓				
	Rural (fields/forest)				✓				
Form of output			LOS Score	Index	Index	LOS Score	Relative Attractiveness	Equivalent Distance	Model Coefficient

Table 5. Link time scaling factors, derived from Portland study

Facility description	Time scaling factor	
	Commute	Non-commute
Bike lane	1.00	1.00
No bike lane; 10,000-20,000 vpd	1.37	1.22
No bike lane; 20,000-30,000 vpd	2.40	2.37
No bike lane; 30,000+ vpd	8.16	7.19
Bike path	0.84	0.74

Table 6. Intersection effective delays, derived from Portland study (turns converted to NZ)

	Time delay (s)	
	Commute	Non-commute
Traffic signal*	6.1	10
Stop sign	1.4	2.6
No signal, Right turn; 10,000-20,000 vpd	27	47
No signal, Right turn; 20,000+ vpd	67	120
No signal, Left turn; 10,000+ vpd	11	19
No signal, crossing*; 5,000-10,000 vpd	12	21
No signal, crossing*; 10,000-20,000 vpd	17	30
No signal, crossing*; 20,000+ vpd	93	180

* excluding Left turns

METHOD

Cyclists in typical network models are presumed to select the route between the origin and destination that provides the shortest travel time. In this instance, travel time is termed an *impedance* attribute, as it acts to oppose cyclist flow. Travel time is the most widely used impedance attribute in transport modelling, but travel distance or travel cost are also often used.

When used as an impedance attribute in cycle network models, travel time is often calculated by assuming that cyclists travel a constant speed along all types of link. Refinements to this assumption can include accounting for intersection delays or the higher effective speeds that can potentially be attained using off-road paths. An example of the differences between impedance minimisation for distance and time (with intersection delays) is shown in **Figure 2**.

The aim of this research is to develop an improved impedance measure for cycling that accounts for the preferences that cyclists have for certain types of cycle facilities. A range of factors may influence this preference, most notably the perception of safety along certain network links. This research develops a method that defines a new impedance attribute, the Abley Cycle Route-Choice Metric (ACRM), which is based upon link travel times that are weighted to account for this cyclist preference.

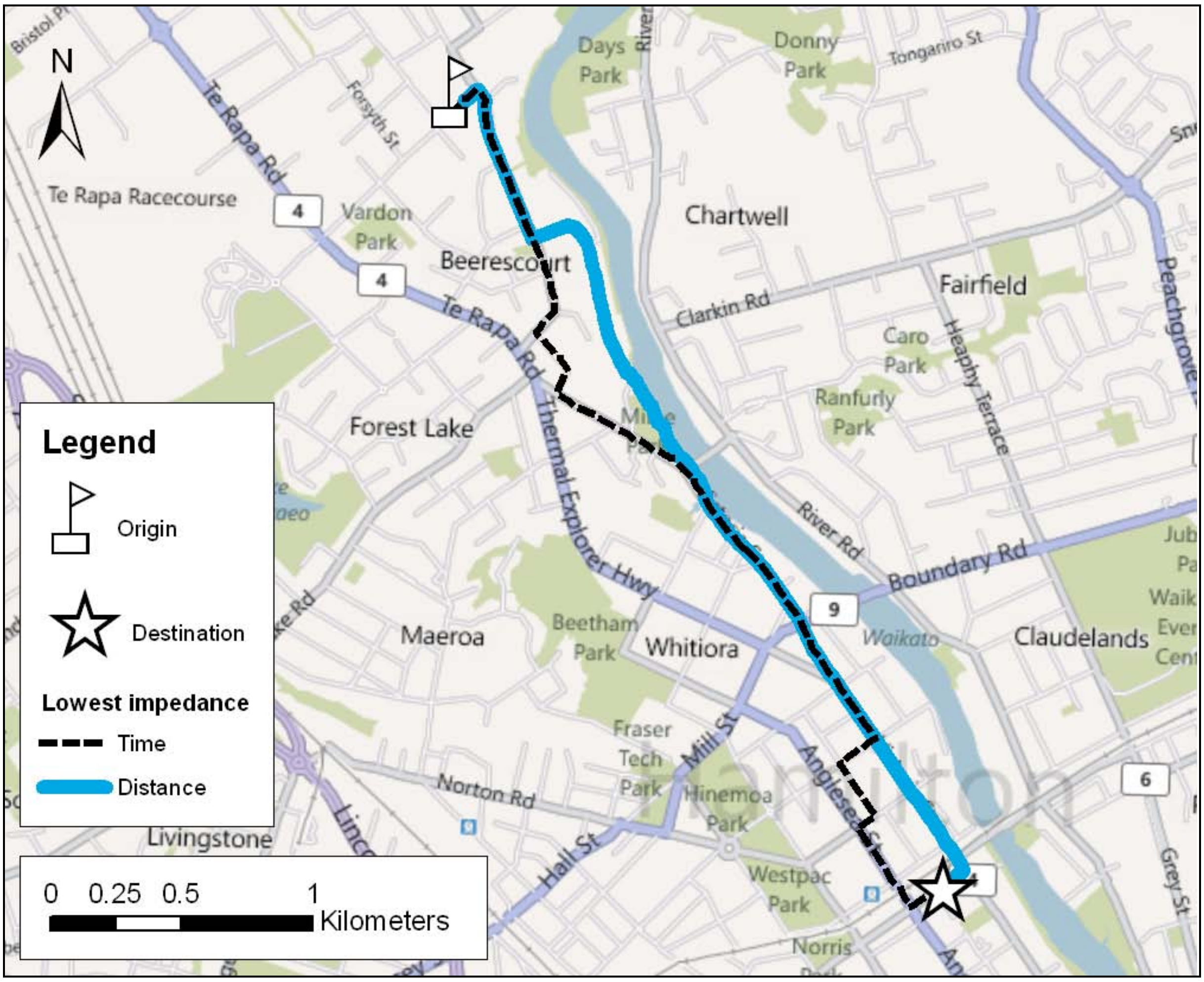

Figure 2. Comparison of shortest distance and shortest time (with intersection delays) cyclist routes.

Prior to applying the selected methodology to New Zealand, the model values required some calibration. Although it seems obvious that New Zealand cyclists would prefer the same facilities as Portland cyclists; it was desirable to test whether the same *extent* of preference is exhibited. To avoid repeating the entire Portland study in a New Zealand context, New Zealand cyclist behaviour was tested and compared to Portland values, allowing time trade-offs to be scaled based upon the results of the comparison. For example, the Portland results found that *"half of all observed trips were less than 10 percent longer than the shortest path, and 95 percent of trips were less than 50 percent longer*." Comparative deviation figures were calculated for cycling in New Zealand, allowing the creation of a scaling function for applying the Portland results to New Zealand. This process is described in the following section.

Scaling Function Calculation

In 2007 Beca Infrastructure Ltd prepared a cyclist survey for the Christchurch City Council to aid in the Christchurch Cycle Network Plan. The project recruited 400 cyclists for a week long survey of their cycling activity. The survey participants were selected by a random telephone sample, with an equal number of participants from each community ward in the city. In total, the surveyed participants made nearly 4,000 cycling trips. Participants drew their cycle routes on maps, which Beca then digitised into a GIS format.

Of the recorded trips, 1,527 were available for analysis after the following were removed:

- trips for the purpose of recreation or sport, and trips without specified destinations/purposes
- trips for which there was no unique identifier (required for linking GIS routes with spreadsheet data)
- circular trips
- trips outside the network
- trips with obvious mistakes or digitising errors

The distance of the actual route for a trip was compared to the shortest distance path along the cycle network for the same origin and destination. A further 349 trip legs were removed after this process, for which the actual distance was less than the calculated shortest distance (indicating digitising errors or inadequacies with the cycle network being used for comparison, although for 75% of these trips the deviation was less than 5%). The results of this analysis for Christchurch indicated that 72% of observed trips were less than 10% longer than the shortest path, and 98% of trips were less than 50% longer than the shortest path. For Portland these numbers were 50% and 95%, respectively. This indicates that Christchurch cyclists choose paths which more closely match their shortest path, compared to cyclists in Portland. If the permeability of the cycle network in Christchurch is assumed similar to that of Portland (i.e. the differences are due to preference, not geography and networks), the values indicate that New Zealand cyclists have:

- a lower preference against unfavourable facilities and
- a lower preference for favourable facilities; compared to the Portland respondents.

This means the time scaling factors in New Zealand will be closer to 1.00 for all facility types.

A curve was interpolated to fit the three reported Portland values for percentage of trips versus percent deviation from shortest path. Previous research by Abley Transportation Consultants Limited indicates that logistic curves, those that follow the general formula shown in **Equation 1**, provide the best fit to deterrence data of this form. A similar curve was fitted to the entire set of Christchurch cyclist results. Both sets of data and the interpolated curves are shown in **Figure 3**. The fitting parameters and R^2 values of the fitted curves are given in **Table 7**. To calculate the *percent greater than shortest path* corresponding to a known *percent of trips*, Equation 1 can be rearranged to solve for *x*, as shown in **Equation 2**.

Equation 1. Generalised form of the scaled (such that y(0)=1) logistic function

$$y(x) = \frac{1 + e^{-\alpha\beta}}{1 + e^{\beta(x-\alpha)}}$$

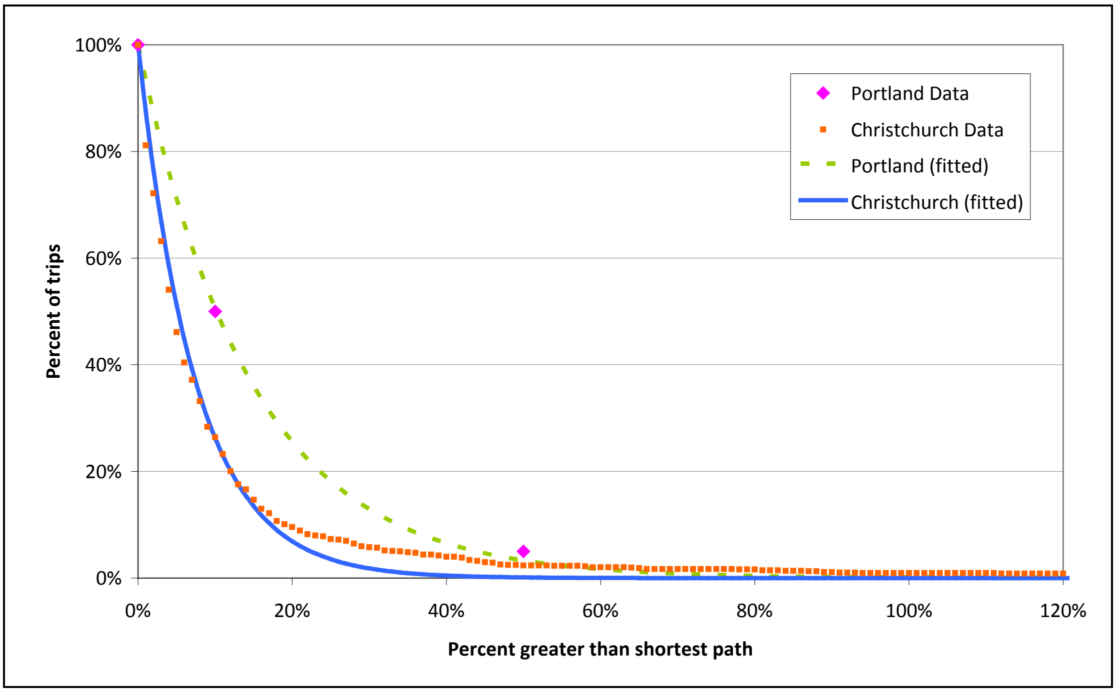

Figure 3. Data and fitted logistic curves for Portland and Christchurch

Table 7. Fitting parameters and R^2 values

Location	Variable		
	α	β	R^2
Portland	-319	0.068	0.999*
Christchurch	-143	0.134	0.979

* R^2 value is artificially high due to the low number of input samples

Equation 2. Generalised scaled logistic function rearranged to solve for x

$$x = \frac{\ln\left(\frac{1+e^{-\alpha\beta}}{y}-1\right)}{\beta}+\alpha$$

Using the fitted curves, Portland time scaling factors contained in Table 5 were mapped to New Zealand, based upon a constant percentage of trips between both areas. The scaling factor conversion is applied through two major steps:

1. calculate the percentage of trips (*y*) corresponding to the time scaling, presented as a percent deviation from the shortest path (*x*), using Equation 1 with Portland α and β values
2. as this percentage of trips (*y*) is constant over both areas, use Equation 2 with Christchurch α and β values to calculate the percent deviation from the shortest path (*x*)

An example of converting the scaling factor for non-commute trips on roads with no bike lane and 10,000-20,000 vehicles per day is shown in **Figure 4**. The relevant Portland time scaling factor, 1.223 (rounding removed), equates to 22.3% greater than the shortest path, the corresponding percentage of trips (calculated with Equation 1) is 21.8%. This value is constant between both areas, consequently the percent greater than shortest path value for Christchurch is calculated by passing 21.8% into Equation 2, which produces a value of 11.4%, equivalent to a time-scaling of 1.11 (rounded to 3SF).

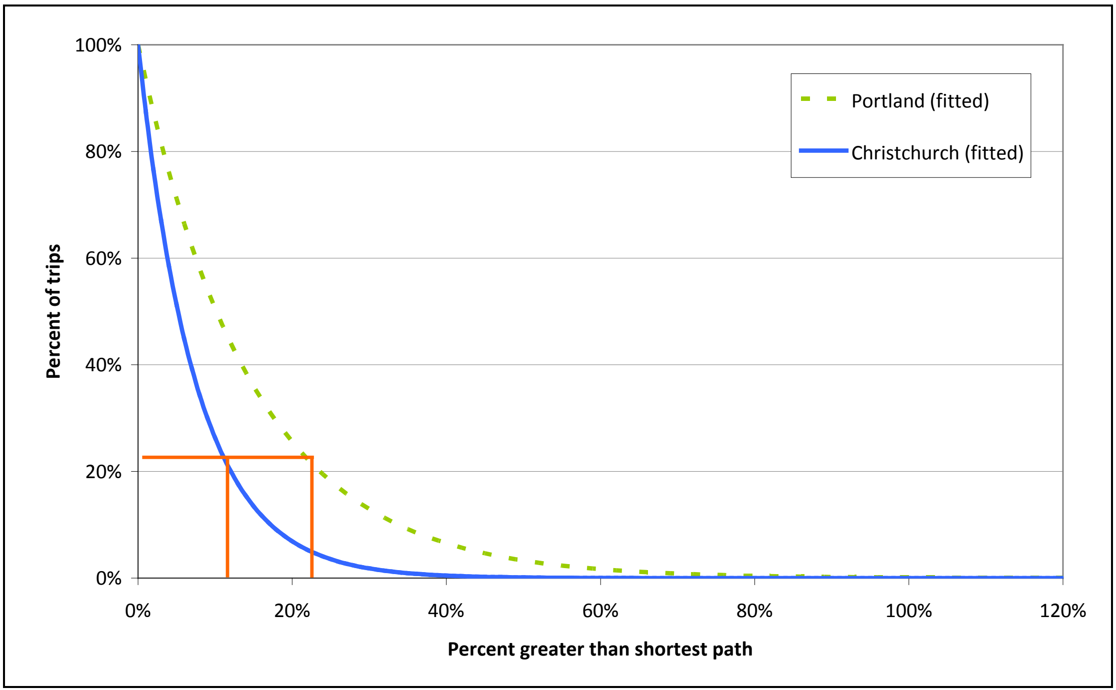

Figure 4. Example time-scaling factor conversion from Portland to New Zealand

RESULTS

The calculated New Zealand time scaling factors are presented in **Table 8**. The values are used to scale the initial link travel time; for example, if the travel time along a link is 30 seconds and it is a section of road with no bike lane and a traffic volume of 10,000-20,000 vehicles per day, the perceived travel time, due to the unattractiveness of the facility, would be 33 seconds. Intersection delays, converted to New Zealand values by the same method described above for links, are given in **Table 9**.

Table 8. Portland and New Zealand link time scaling factors

Facility description	**Time scaling factor**			
	Portland		**New Zealand**	
	Commute	**Non-commute**	**Commute**	**Non-commute**
Bike lane	1.00	1.00	1.00	1.00
No bike lane; 10,000-20,000 vpd	1.37	1.22	1.19	1.11
No bike lane; 20,000-30,000 vpd	2.40	2.37	1.71	1.70
No bike lane; 30,000+ vpd	8.16	7.19	4.65	1.46
Bike path	0.84	0.74	0.92	0.87

Table 9. Portland and New Zealand intersection effective delays

Facility description	Time delay (s)			
	Portland		New Zealand	
	Commute	Non-commute	Commute	Non-commute
Traffic signal*	6.1	10	3.1	5.3
Stop sign	1.4	2.6	0.7	1.3
No signal, Right turn; 10,000-20,000 vpd	26	47	13	24
No signal, Right turn; 20,000+ vpd	67	130	34	64
No signal, Left turn; 10,000+ vpd	11	19	5.6	9.9
No signal, crossing*; 5,000-10,000 vpd	12	21	6.1	11
No signal, crossing*; 10,000-20,000 vpd	17	30	8.7	15
No signal, crossing*; 20,000+ vpd	93	180	48	91

* excluding Left turns

The combination of the values in Table 8 and Table 9 form the Abley Cycle Route-Choice Metric (ACRM). The effect of the scaling factor and the difference in selected route using the ACRM on a real network is shown in **Figure 5**. The ACRM route makes extensive use of the bike path adjacent to the river, avoiding busy roads and intersections.

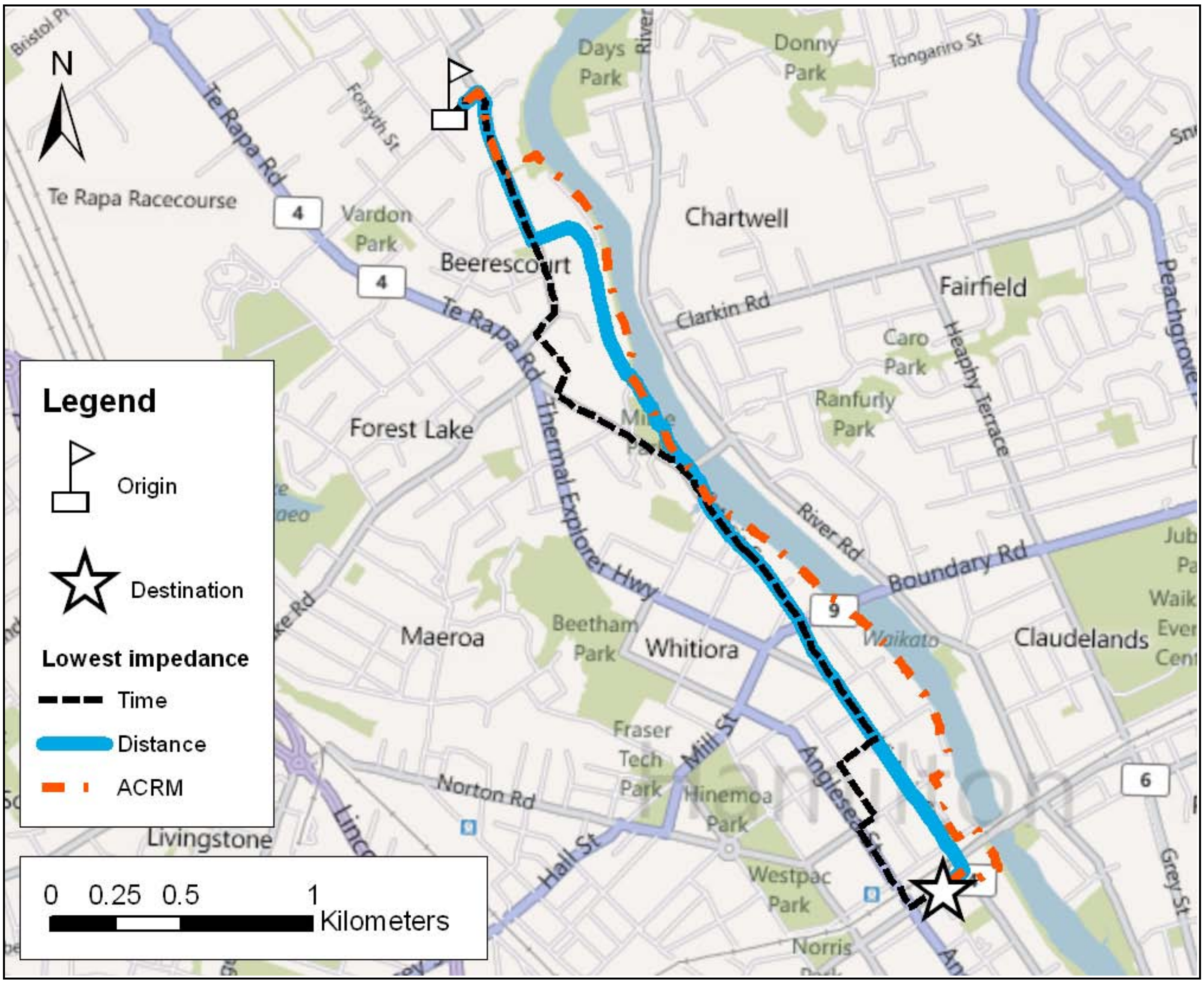

Figure 5. Comparison of shortest distance, shortest time (with intersection delays) and Abley Cyclist Route-Choice Metric (ACRM) cyclist routes.

Applying the ACRM to a Cycle Network in GIS Representation

The ACRM has been applied to the Hamilton City cycle network as part of its accessibility model, which is currently being developed for the Hamilton City Council by Abley Transportation Consultants Limited (Abley 2010). Travel times along all links were initially calculated as distance divided by velocity, based upon an assumed speed of 20km/h (Austroads 2011). Link times were then scaled by the values shown in Table 8, depending upon the link facility type. The average inter-peak traffic signal delay in Hamilton is 30 seconds; the delays for all signalised movements described in Table 9 were additional to this value. Delays for left turns at traffic signals were set directly to the average inter-peak delay. Left turning motions excluded from Table 9, and any intersection types not represented in Table 9, were set to a default confirmation delay of two seconds.

DISCUSSION

The new Abley Cycle Route-Choice Metric (ACRM) developed by this research represents a significant improvement over existing New Zealand cyclist route choice methods, as it accounts for the preferences that cyclists have for certain types of facilities. The research is based upon analysis of revealed preference (RP) survey data collected in Portland, Oregon through the use of GPS devices. Survey results were analysed by the Portland researchers to produce ‘relative distance’ figures, which represent the distance a cyclist would be further willing to travel to avoid various types of roadway facility or intersection. For this research, these figures were represented as time scaling factors then mapped to account for observed differences between New Zealand and Portland cyclists, producing a series of New Zealand time scaling factors and intersection delays that reflect cyclist preferences.

Application of the Portland results to New Zealand is based upon the significant assumption that the permeability of the Christchurch cycle network is similar to that of Portland. This assumes that the differences highlighted in Figure 3 are due to cyclist preference, not geography or networks. Although, in comparison to Christchurch, a greater amount of Portland is laid out in a highly connected grid pattern, a river separates Portland’s central business district from the largely residential areas east of the river. Proposed future work for this research is to further investigate the cycle permeability differences between Portland and Christchurch, with the potential to account for any differences through modifications to the mapping functions.

For comparison, the calculated time scaling factors were contrasted with the relative attractiveness values (adjusted such that a bike lane with on-street parking has a value of 1.0) from the NZTA Economic Evaluation Manual (EEM). Values for each of the facilities represented in the EEM are compared in **Table 10**.

Table 10. ACRM link time scaling factors compared to the NZTA Economic Evaluation Manual values

Facility description	Time scaling factor		NZTA EEM
	Commute	Non-commute	
Bike lane	1.00	1.00	1.00
No bike lane; 10,000-20,000 vpd	1.19	1.11	1.44
No bike lane; 20,000-30,000 vpd	1.71	1.70	
No bike lane; 30,000+ vpd	*4.65*	*4.16*	
Bike path	0.92	0.87	0.89

The values show a high level of similarity; the EEM value for bike paths falls directly between the commute and non-commute time scaling factor. The EEM value for roads without bike lanes, which is effectively a weighted average over all vehicle volumes, is very close to the average of the four bike lane figures for lower vehicle volume time scaling factors (both commute and non-commute for 10,000-20,000 and 20,000-30,000 vehicles per day), 1.43. Notably, few roads that cyclists are allowed to use have greater than 30,000 vehicles per day, hence this figure will have a limited influence upon the EEM value. The similarity between the calculated values and the EEM values lead to three possible conclusions that will be further tested as future work for this research:

1. The methodology of mapping cyclist preferences between countries is approximately valid.
2. Differences between the results of well designed stated and revealed preference surveys are not significant when analysing cyclist route choices.
3. Either the permeability differences between Portland and Christchurch are insignificant, or the differences are potentially significant but the EEM values include survey responses for New Zealand cities with various levels of permeability (implying that the similarities in Table 10 are coincidental, and Christchurch responses cannot be directly extrapolated to New Zealand).

The Abley Cycle Route-Choice Metric developed by this research presents a significant improvement to previous methods of cyclist modelling in New Zealand. Even though the calculated time scaling factors show a high level of similarity with other New Zealand research, most notably the NZTA EEM, this research has calculated factors that are sensitive to a much wider range of roadway variables for segments than the EEM. Additionally the Abley Cycle Route-Choice Metric also represents effective intersection delays as a result of cyclist preference to avoid different types of intersection.

This research was undertaken as part of the Hamilton city accessibility model, currently being developed for the Hamilton City Council by Abley Transportation Consultants Limited (Abley 2010). Outputs of this research will allow the model to better account for cyclist preference when investigating accessibility. In a wider context, the outputs of this research will enable smarter inter- and intra-network connections to be identified, and will assist in identifying the real costs and benefits of proposed transport infrastructure projects that will impact upon cyclists. In turn, this will enable improved forecasting of cyclist demand, and induced demands as a result of new facilities.

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