**MEASURING THE CYCLING LEVELS OF SERVICE**

**IN WELLINGTON – HOW BAD IS IT?**

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**ABSTRACT**

This paper is based on a study commissioned by Wellington City Council (WCC) to carry out the Cycle Network Gap Study of 19 largely urban routes covering approximately 120km of the network. This paper documents the findings of the first phase of the study to determine a methodology for assessing the cycling Level of Service (LOS) for different segments and whole routes, and to state the cycling LOS for the 19 selected routes.

The main overarching objective of this project is to support WCC’s commitment to contribute towards cycling becoming safer and more convenient.

The study team completed an in-depth analysis of eight different methodologies identified as reasonable for calculating a cycling LOS. The study team also developed three modified methods to test. A Danish methodology is considered most appropriate for assessing cycling LOS. During the assessment a number of opportunities were identified that could enhance the cycling LOS. These have been tested using the recommended methodology and the resulting cycling LOS predicted.

**INTRODUCTION**

This paper is based on a study commissioned by Wellington City Council (WCC) to carry out the Cycle Network Gap Study of 19 largely urban routes covering approximately 120km of the network. This paper documents the findings of the first phase of the study to determine a methodology for assessing the cycling Level of Service (LOS) for different segments and whole routes, and to state the cycling LOS for the 19 selected routes.

The main overarching objective of this project is to support WCC’s commitment to contribute towards cycling becoming safer and more convenient. To support this, the Cycle Network Gap Study includes the following tasks:

1. Development of cycling LOS assessment methodology
2. Undertake the cycling LOS assessment on existing routes
3. Identify areas for improvement and recommendations for improvements
4. Assess future cycling LOS based on identified improvements
5. Prioritise improvements
6. Final report

This paper describes the work undertaken under step one and step two of this wider study. This paper describes the cycling LOS on the 19 selected routes.

The review of existing methodologies identified a large number of variables that can be used to determine a cycling LOS; each of these was considered in developing an assessment methodology for WCC. Draft option assessment criteria were developed and discussed with WCC officers and with stakeholders, prior to agreeing a preferred methodology.

An assessment using various methodologies for determining cycling LOS on a selection of the routes already reviewed for WCC was carried out to help determine which methodology best suited Wellington. The purpose of the review was to define the most appropriate factors with their possible weightings. This could subsequently be used to establish a list or prioritised factors in a future or modified methodology to improve the measurement of cycling LOS.

**REVIEW OF INTERNATIONAL CYCLING LOS METHODOLOGIES**

Determining a cycling level of service LOS is a concept that has mostly been developed over the last 20 years and estimations on how this should be calculated vary widely. Although the LOS assessments have limitations they are helpful in comparing routes by providing an analysis of the outcomes of various options (using the same variables) or of the impacts when changing individual or combined variables in the methodology. One of the key benefits of this type of assessment is that it is an independent and objective measure that can be applied to a network of routes to identify the variance that exists between LOS.

The study team reviewed eight different methods, which proposed models for calculating a cycling LOS. A comprehensive summary of the findings from this review is contained in this paper. Also included is an analysis of three additional methods, developed by modifying the preferred methodologies, which attempt to address some of the drawbacks of the more popular methods.

As is the case with traffic and pedestrian related LOS, cyclist LOS is reported using the letters of A through F, with A and B considered good, C and D average, and E and F poor.

Most of the methods that are used focus on link analysis as opposed to assessing links and intersections. This does result in intersections sometimes not being considered in the assessment. This is important to remember as intersections are often the locations that act as a barrier to cycle routes.

The methods are summarised below. Interested parties can obtain the full details of the methodologies used by contacting the authors.

## Method 1 – National Cooperative Highway Research Program (NCHRP) Report 616 (2008)

NCHRP Report 616 (2008) recommends that the level of service calculation for cyclists be determined by a weighted combination of cyclists’ experiences at intersections and midblocks (on street segments in between the intersections). The study used two different models for segments, which match video clip responses between 27% and 46% of the time. Findings from this report seem to help form the basis of the Highway Capacity Manual 2010 (see method 5 and 6 below) evaluation criteria.

This model utilises most of the prevalent factors used in the studies reviewed. The main drawback of the method is that it uses two different models with each having different issues. The first model could not predict LOS at A/B but was better at predicting poorer levels of service (C/F). The second model has an overall higher match rate to user rating mostly due to its ability to predict LOS A/B.

## Method 2 – Trafitec Danish Roadway Segment Cycling LOS (2007)

Jensen (Jan 2007) produced what is commonly referred to as the Danish method. This was developed in conjunction with a pedestrian model and attempted to objectively quantify pedestrian and bicyclist stated satisfaction with road sections between intersections. People were randomly selected to participate in a video review. Variables with the largest effect on cyclist satisfaction were the type and width of bicycle facility; and the distance to motor vehicles and pedestrians. A ‘user-friendly’ spreadsheet was developed using some of the more key variables including, traffic volume, speed, type of area, and cross section of the roadway segment.

This model utilises most of the prevalent factors used in other methods. When compared overall the Danish and American models evaluate cycling LOS similarly. This methodology is closely aligned with the NZTA Cycle network and route planning guide. The Danish cycling LOS calculation also makes some allowance for pedestrian interactions.

One drawback of this particular method is that it does not account for intersections or other access conflicts. In addition Danish user expectations for a separate bike path are high and may influence the study findings and relative ranking of criteria. This method also excludes heavy vehicle and surface condition influences in the recommended model. (A list of the factors included for each assessment methodology is summarised in Table 1 in the Critical Factor/Criteria Summary section of this paper.)

## Method 3 – Trafitec Danish Roadway Intersection Cycling LOS (2012)

Trafitec (Jensen, 2012) is a bicycle model which was completed in conjunction with a pedestrian model that looked at intersection LOS for both modes. Whether cyclist facilities were present and the types of those facilities present were found to be the most important variables to cyclists. Traffic volumes were also found to be a significant factor. Waiting time and vehicle speed was only found to play a minor role.

This model is one of very few to rate cycling LOS for a variety of different intersections, however, the Danish road rules for cyclists turning across traffic are different than most other countries which influence some of the calculations and findings.

## Method 4 –Transportation Research Record 1538 (1996)

Dixon (1996) recommends “*bicycle LOS performance measures [that] were tested on nine arterial and three collector roadways in Gainesville, Florida. The results were bicycle LOS ratings of B, C, D, and E on these corridors. The results were reviewed by three advisory committees of the Gainesville Metropolitan Planning Organisation. These committees included technical staff and local citizens with high levels of training and experience in bicycle and pedestrian usage. Committee members’ anecdotal and personal experiences suggested that the assigned corridor LOS ratings accurately describe existing bicyclist and pedestrian conditions. The committees produced a list of bicycle and pedestrian project priorities, which, when compared to the results of this LOS analysis, revealed a correspondence between roadways with low LOS and roadways identified as needing improvements. Roadways that are high on the project-needs list for bicycle or pedestrian improvements generally received a low LOS rating*.”

This method also utilises most of the criteria prevalent in the reviewed studies and is the only study to have a multi-modal (Bus/Train transfer) influence included in the cycling LOS calculation.

This is one of the older studies in the cycling LOS research literature. The measure of system performance was mainly evaluated qualitatively by people involved in planning committees. The model is simplistic and, therefore, may not accurately capture the relative weightings of different criteria.

## Method 5 – Highway Capacity Manual (HCM) 2010 – Full Facility Cycling LOS Calculation (2010)

The Highway Capacity Manual (2010) bicycle methodology is applied through a series of eight steps that culminate in the determination of the facility cycling LOS. A separate methodology for evaluating off street bicycle facilities is provided in HCM Chapter 23 (Off Street Pedestrian and Bicycle Facilities) which was not applied for this study.

This methodology utilises most of the prevalent factors in the methodologies reviewed and includes combining links and intersections into one facility calculation. The HCM has a significant amount of peer review and outside input while also utilising fairly new research data.

A number of drawbacks of the methodology have been identified. Many types of intersections are not yet included due to lack of consensus on how to deal with them. Another issue is in calculating segment cycling LOS. The equation adds a constant which consequently, makes it difficult to achieve a segment cycling LOS better than C, even if the link and intersection have cycling LOS A. In turn, facility cycling LOS will also result in LOS C or worse. Another drawback is that a completely different cycling LOS calculation is required with different inputs for an off-street facility. Also in all HCM methodologies it is assumed that the gradient is not in excess of 2%, which is not the case on many of Wellington’s routes.

## Method 6 – Highway Capacity Manual 2010 – Link cycling LOS Calculation (2010)

HCM (2010; Chapter 17– Steps 5 and 6 of the bicycle facility methodology) can be used as a stand-alone procedure for a link-based evaluation. This approach is regularly used by local, regional and state transportation agencies in the USA. It offers the advantage of being less data intensive than the full, eight-step methodology described in method 5 above and produces results that are generally reflective of cyclists’ perceptions of service along the roadway. This method can be especially appealing when agencies are performing network wide evaluation for a large number of roadway links. This approach precludes an integrated multimodal evaluation because it does not fully reflect segment performance.

The methodology utilises most of the variables prevalent in the reviewed methodologies. The HCM cycling LOS method is considered state-of-the-art. It builds on dozens of earlier studies and was developed through a massive effort to improve the HCM for non-motorised travel. It is used by many agencies to model and analyse their cycle networks.

Major drawbacks of this method are that it precludes some key influences such as intersections (or other conflicts) as well as gradients in excess of 2%.

## Method 7 – Florida Department of Transportation (2006)

The Florida Department of Transportation Roadway Facility Bicycle LOS models are built on adopted segment and intersection bicycling level of service models. Data for the new cycling LOS was obtained from a field data collection event and video simulation conducted in 2005. This was used to create a user-calibrated method which could be used to rate a wide range of roadway conditions for how well they serve the bicycle.

Again the model utilises most of the criteria prevalent in the reviewed methods and includes the ability to combine links and intersections into one facility calculation. However, this model does not include some key influences such as intersections other than unsignalised (or other conflicts), on street parking and type/width of bike facility provided.

## Method 8 – Nga Haerenga – The New Zealand Cycle Trail Design Guide Version 3 (2012)

The Cycle Trail Design Guide (2012; version 3) was published to assist people involved in the planning, designing or building of cycle trails that would make up the New Zealand Cycle Trail (NZCT). The basis for the trail design is the selection of a trail grade and recognition of the trail grade criteria. The selection will reflect a target audience from easy grade 1 trails to higher-grade trails, which test fitness and skill. Overall the guide uses a trail grade rating system based on route factors, many of which are typically used in other cycling LOS calculations.

Even though the trail guide does cover both on road and off road paths the vast majority of the NZCT consists of off-road trails with the main emphasis being on recreational cyclists catering mainly to mountain bikes.

The trail grading system uses many of the criteria prevalent in the reviewed methods and includes some allowance for intersection rating. However, this model has limited use in an urban area where many of the trails will be on road and a wider range of bicycles will likely be encountered.

## Critical Factor/Criteria Summary

Table 1 summarises the factors used in the methods reviewed and enables the prevalence of factors to be easily determined. Several critical factors are present in most methods, namely motor vehicle volume, vehicle speed and cross section characteristics.

Table 1 was used to review the criteria present in the models to determine which methods used most factors as well as to look at some potential modifications to existing methodologies to ensure that the most critical factors where accounted for. Following the review of each of the methodologies and a consideration of the variables used in determining cycling LOS it was determined that Methods 2, the Danish Method, and 6, the HCM Link Method, were preferred. These two methods are proven methods and the review of the others methods did not reveal any major deficiencies Method 2 or 6.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Method** | | | | | | | | No. of Criteria Used |
| **Level of Service Criteria** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Vehicle volume | x | x | x | x | x | x | x | x | 8 |
| Average speed of vehicles | x | x | x | x | x | x | x | x | 8 |
| Number of lanes | x | x | x | x | x | x | x |  | 7 |
| Width of outside through lane | x | x |  | x | x | x | x | x | 7 |
| Surface rating | x |  |  | x | x | x | x | x | 6 |
| Width of shoulder/riding area | x | x |  | x | x | x |  | x | 6 |
| Conflicts (bus stops, access, intersections) | x | x |  | x | x |  | x |  | 5 |
| Proportion of heavy vehicles | x |  |  | x | x | x | x |  | 5 |
| On-street parking | x | x |  | x | x | x |  |  | 5 |
| Type of facility provided, presence of buffer |  | x | x | x | x |  |  |  | 4 |
| Crossing distance at intersection | x |  | x |  | x |  |  |  | 3 |
| Presence of kerb or median |  |  |  | x | x | x |  |  | 3 |
| Land use |  | x | x |  |  |  |  |  | 2 |
| Volume of vehicles with conflicting movements |  |  | x |  | x |  |  |  | 2 |
| Type of intersection |  |  |  |  | x |  |  | x | 2 |
| Pedestrians passed or presence |  | x |  |  |  |  |  |  | 1 |
| Signal waiting time |  |  | x |  |  |  |  |  | 1 |
| Multi modal support |  |  |  | x |  |  |  |  | 1 |
| Bicycle running speed |  |  |  |  | x |  |  |  | 1 |
| Bicycle lane capacity |  |  |  |  | x |  |  |  | 1 |
| Bicycle delay |  |  |  |  | x |  |  |  | 1 |

**Table 1: Cycling LOS Criteria in the Reviewed Methodologies.**

**MODIFIED METHODOLOGIES CONSIDERED**

After reviewing the methodologies and the criteria used the study team decided to consider options for modifying the preferred methodologies to see whether it was possible to enhance and localise the Danish Method (method 2) and the HCM Link Method (method 6). Three modified methods are discussed below.

## Modified HCM Link– Modified Method #6a

The study team used the base HCM Link Methodology (method 6) and attempted to add in several other factors which were believed to be important variables but were not accounted for in the link calculation.

The proposed modified method was based on HCM link methodology along with some potential factors specific to Wellington and adjusted for best fit with the Danish Methodology.

Additional factors included were in relation to:

* + Number of conflict points (bus stops, driveways, intersections, etc)
  + Gradient of cycle route
  + Effect of wind

The rationale for the proposed calculation was based on the findings from the review of all the methodologies where access conflicts made up 10-15% of overall consideration in many of the studies reviewed. Therefore 85% of the cycling LOS for consideration was determined by the standard link calculation and 15% of the cycling LOS was determined by the local or additional factors that were felt to be important (Conflicts, Gradient, and Wind).

## Modified HCM Link– Modified Method #6b

Upon further review by the study team the HCM Link Methodology (Method 6) was modified a second time in order to try to simplify the calculation as much as possible. This also was done in order to concentrate on factors which a road controlling authority could realistically change.

Based on HCM link methodology additional factors included were:

* + Fi = Factor for bicycle accommodation at intersections.

Factors removed from the standard HCM link analysis were:

* + Fp =Pavement Condition
  + Percentage of Heavy Vehicles (sub-factor of Fs)

## Modified Danish Road Segment – Modified Method #2a

Following the development of the above methodologies, the study team proposed a modified Danish model that would include some additional factors not currently in the Danish Methodology (method 2). The modified methodology was thus based on the standard Danish roadway segment methodology and included additional factors related to:

* + Pavement Condition
  + Number of Conflicts (i.e. number of residential accesses, commercial/industrial accesses and roadway intersections)

**COMPARISON OF CYCLING LOS METHODOLOGIES IN WELLINGTON**

In order to compare different model outputs several different methodologies were run on a test route from Island Bay to the CBD. The route was broken down into segments of similar characteristics and then each segment was assessed individually. A sample of the outputs for The Parade northbound from The Esplanade to the Dee Street roundabout on the Island Bay to CBD route can be found in Table 2 below.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | | | | | |  | | |  | |
| **Roadway Segment** | **HCM Link cycling LOS**  **(Method 6)** | **Danish cycling LOS**  **(Method 2)** | | **Modified HCM #6a cycling LOS** | | **Modified HCM #6b cycling LOS** | | | **Modified Danish #2a cycling LOS** | | |
| Derwent/Esp int | C | | E | | E | | D | | | F | |
| Derwent pkg | D | | E | | D | | E | | | E | |
| Derwent no pkg | D | | D | | D | | E | | | D | |
| Derwent-Parade | C | | E | | D | | D | | | D | |
| Parade/Reef int/bus | B | | F | | D | | C | | | F | |
| Parade cyc | B | | C | | B | | C | | | C | |
| Parade/Humb int/bus | C | | F | | D | | D | | | F | |
| Parade cyc | A | | C | | B | | B | | | C | |
| Parade/Mersey int/bus | D | | F | | E | | E | | | F | |
| Parade cyc | B | | C | | C | | C | | | C | |
| Parade/Medway int | D | | E | | D | | D | | | E | |
| Parade shops 30kph | D | | D | | D | | E | | | D | |
| Parade no cyc | D | | F | | E | | E | | | F | |

**Table 2: Cycling LOS on Island Bay to CBD route using different methodologies**

Largely the methodologies agreed within one level of service, however, in some instances larger differences were found. An example of an area where there are large differences is due to the presence of bus stops, which the Danish methodology takes into account and weights this variable as more negative than other methods. This is evident in the segments identified in yellow. In general the HCM Link (unmodified) method seemed to determine a higher cycling LOS mostly due to low percentage of heavy vehicles, and decent pavement conditions on this route.

Although it was considered that there is merit in choosing a modified methodology to reflect Wellington specific variables, it was not felt that there were sufficient deficiencies in the proven and tested methodologies to support modification. Based on anecdotal evidence, supported by advice and consideration by stakeholders and officers from WCC, it was determined to move forward with a review of the 19 routes using the unmodified Danish Methodology (method 2).

**CYCLING LOS RESULTS FOR WELLINGTON**

The Danish Method (method 2) was applied to the 19 selected routes around Wellington. Each route was broken down into segments, as in Table 2 above, based on similar characteristics. To determine the overall LOS for the route, a weighted average was assessed based on segment length. The results of this analysis are presented in Table 3.

|  |  |  |  |
| --- | --- | --- | --- |
| **Route** | **Route** | **Length (Km)** | **Cycling LOS** |
| 1a | Kelburn Viaduct to Karori | 9.9 | E |
| 1b | CBD to Kelburn Viaduct | 6.8 | E |
| 2a | Karori to Ottawa | 11.0 | E |
| 2b | Ottawa to Johnsonville | 8.9 | E |
| 3 | Ngaio to Hutt Road | 5.2 | F |
| 4a | Tawa to Glenside | 4.8 | E |
| 4b | Glenside to Johnsonville | 4.6 | F |
| 5 | Newlands to Johnsonville | 3.1 | E |
| 6 | Newlands to Hutt Road | 7.7 | F |
| 7 | Thorndon | 4.3 | E |
| 8 | Oriental to Kilbirnie via Evans Bay Parade | 8.8 | D |
| 9 | Cobham | 1.6 | B |
| 10 | Airport Route | 2.6 | C |
| 11 | Broadway to Seatoun Coast | 4.3 | E |
| 12 | Mt Vic Tunnel to Evans Bay Parade | 2.4 | E |
| 13a | Newtown to Kilbirnie | 3.6 | F |
| 13b | Rongotai to Cobham | 1.3 | E |
| 14a | CBD to Brooklyn | 2.4 | E |
| 14b | Brooklyn to Owhiro Bay | 9.5 | E |
| 15 | Willis | 1.9 | F |
| 16 | The Terrace to Kelburn Viaduct | 2.1 | F |
| 17 | Aro St to Chaytor | 5.9 | E |
| 18 | The Terrace | 3.0 | F |
| 19 | Onepu Road | 2.4 | F |

**Table 3: Routes and their corresponding cycling LOS.**

Not all links in Wellington are homogenous and the cycling LOS will clearly vary on routes within the whole network, however, the chosen routes are not only considered representative they actually cover most of the main routes into the CBD. The answer to the question posed at the start of the paper; measuring the cycling LOS in Wellington, how bad is it? requires an entire network review. Based purely on the selected methodology and the 19 routes in question it can be concluded that the existing cycling LOS in Wellington is somewhere between poor and average. This is borne by the evidence from the evaluation of the routes as indicated in Table 3 above.

**CONCLUSIONS**

The study team carried out an analysis of eight different methodologies identified as reasonable for calculating a cycling LOS. In addition, the study team also developed three additional modifications to the selected methodologies which were tested on a test route. An analysis was completed of all the different factors used in the methods. All of the methods used vehicle volumes, speed and number of lanes, however, there were a range of other factors also assessed (as provided in Table 1).

The two most recent and mainly accepted methodologies, HCM Link Method (method 6) and the Danish Method (method 2) were considered to give a reasonable assessment of the existing and potential quality of the cycling experience along a route. The Danish methodology is considered most appropriate for this purpose, and is closely aligned with the NZTA Cycle network and route planning guide. As the Danish methodology does not include factors for surface condition or access/intersection conflicts these were noted during assessment and will be used in the prioritisation phase of the project.

During the assessment a number of opportunities were identified that could enhance the cycling LOS. These have been tested using the recommended methodology and the resulting cycling LOS predicted. This information will be built upon with other factors such as gradient, cost and potential for new cyclists in the prioritisation of schemes. This is being supported by the work undertaken by this study, which gives clarity as to the current state of cycling LOS using a methodology that has been tested and reviewed in the context of the location.

**REFERENCES**

DIXON, L. B. (1996). Bicycle and Pedestrian Level of Service Performance Measures and

Standards for Congestion Management Systems. Transportation Research Record 1538,

Transportation Research Board

HIGHWAY CAPACITY MANUAL (2010). Urban Street Segments and Urban Signalised Intersections, Chapter 17 & 18, Transportation Research Board

JENSEN, S. U. (2007). Pedestrian and Bicycle Level of Service on Roadway Segments,

Transportation Research Record 2031, Transportation Research Board

JENSEN, S. U. (2012). Pedestrian and Bicycle Level of Service at Intersections, Roundabouts, and other Crossings, Transportation Research Record 2031, Transportation Research Board

LAND TRANSPORT SAFETY AUTHORITY (2004), Cycle network and route planning guide, New Zealand

LANDIS ET AL. (2006). The Roadway Facility Bicycle LOS; Linking the Segment and Intersection Models, Report No. BD545-23, Florida Department of Transportation

MACBETH ET AL. (2012). Cycle Trail Design Guide version 3, Nga Haerenga – The New Zealand Cycle Trail – Ministry of Business, Innovation and Employment

NCHRP (2008). Multimodal Level of Service Analysis for Urban Streets, Transportation

Research Board, Washington, D.C.