Level of Service Model for Bicycle Riders

Prepared for Department of Transport and Main Roads
## Contents

Executive Summary................................................................................................................. iv

1 Introduction ......................................................................................................................... 1
  1.1 Scope of study................................................................................................................. 1
  1.2 Objectives....................................................................................................................... 1
  1.3 Structure of this report.................................................................................................... 2

2 Background ......................................................................................................................... 3
  2.1 Terminology .................................................................................................................. 3
  2.2 Previous studies ............................................................................................................. 4
  2.3 Data requirements.......................................................................................................... 9
  2.4 Limitations of existing approaches................................................................................ 10
  2.5 Which model is ‘best’? .................................................................................................. 10

3 Methodology ....................................................................................................................... 13
  3.1 Outline .......................................................................................................................... 13
  3.2 Online survey ............................................................................................................... 13
  3.3 Stated preference survey .............................................................................................. 13

4 Survey results ..................................................................................................................... 18
  4.1 Summary statistics ......................................................................................................... 18
  4.2 Trip context .................................................................................................................... 22
  4.3 Route choices ............................................................................................................... 25
  4.4 Delayed passing ............................................................................................................. 27
  4.5 On-road facilities .......................................................................................................... 30

5 Discrete choice model ....................................................................................................... 33
  5.1 Outline .......................................................................................................................... 33
  5.2 Discrete choice models ................................................................................................. 33
  5.3 Model estimation ........................................................................................................... 33
  5.4 Dataset .......................................................................................................................... 35
  5.5 Results .......................................................................................................................... 35
  5.6 Model adjustments ....................................................................................................... 41
  5.7 LOS mapping ............................................................................................................... 42
  5.8 Developing the composite route LOS measurement ..................................................... 43

6 Model implementation ....................................................................................................... 44

7 Sensitivity testing ................................................................................................................. 48
  7.1 Outline .......................................................................................................................... 48
  7.2 Motor vehicle interactions ............................................................................................ 48
  7.3 Delay .............................................................................................................................. 51
  7.4 Facility type .................................................................................................................... 53
  7.5 Traffic volumes ............................................................................................................. 56
  7.6 Speed limits ................................................................................................................... 58
7.7 Parking ........................................................................................................... 60
7.8 Summary ....................................................................................................... 60

8 Route choices ................................................................................................. 61
  8.1 Outline .......................................................................................................... 61
  8.2 Example 1: Shared path vs roadway .......................................................... 61
  8.3 Example 2: On-road main road vs quiet street ......................................... 64
  8.4 Example 3: On-road vs On-road with bicycle lanes ............................... 65
  8.5 Example 3: On-road vs On-road with protected bicycle lanes ............. 65

9 Practical examples .......................................................................................... 67
  9.1 Outline .......................................................................................................... 67
  9.2 Link examples ............................................................................................. 67
  9.3 Route examples .......................................................................................... 69

10 Further work .................................................................................................. 73
  10.1 Intersection LOS ....................................................................................... 73
  10.2 Revealed preference calibration ............................................................... 73

11 References ..................................................................................................... 76
## Document history and status

<table>
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<th>Author</th>
<th>Revision type</th>
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Executive Summary

This report describes the development of a mid-block level of service (LOS) model for bicycle riders. The model has the objective of providing the non-technical practitioner with a means to rapidly estimate the LOS of a current link or route, and of the likely LOS with different design alternatives. Furthermore, the model is capable of estimating the proportion of demand that will use competing facilities. This includes the ability to predict demand on competing routes with different types of bicycle facilities, traffic volumes and frequency of delay.

The model was developed from stated preference surveys of bicycle riders in Queensland and Victoria. The model is sensitive to the following parameters:

- facility type (shared path, cycleway, on-road without bicycle lanes, on-road bicycle lanes, on-road protected bicycle lanes)
- frequency of delay due to interaction with other path/road users,
- interactions with other path users (cyclists, pedestrians),
- car volumes,
- bus volumes,
- presence of kerbside parking,
- speed limits (50, 60, 80 km/h),

Models for self-identified cautious and confident riders were developed, such that the analyst can consider the impact of a treatment on both groups independently.

In order to determine the frequency of user interactions a path interactions model is incorporated, based on earlier research. This interactions model provides forecasts of the frequency with which a rider will be delayed or interact with other users on shared paths and cycleways. This interactions model allows users to examine the impact of path width and modal segregation (pedestrians, bicycle riders) on the frequency of interactions. In turn, the LOS model then allows to examine the implications these interactions have on path LOS.

The stated preference surveys were completed by 443 individuals in Queensland and 602 individuals in Victoria, giving a total sample of 1,045 individuals for estimating a discrete choice model. The model behaves in a way broadly consistent with expectations. Some of the key findings from the model were:

- Riders are highly sensitive to the provision of dedicated on-road cycling infrastructure; cautious riders in particular are prepared to divert to use routes with dedicated provision.
- Off-road paths and particularly on-road protected bicycle lanes are strongly preferred to roads without facilities.
- Riders are far more sensitive to interacting with buses on roads than with cars.
- Riders prefer on-road routes without kerbside parking.
Riders are sensitive to delays on paths and roads where they occur every 4-6 minutes or more often. Beyond this range they are largely insensitive to delays.

Riders on shared paths are sensitive to passing pedestrians, but not to passing other bicycle riders.

Two avenues for further research are suggested:

- intersection levels of service, and
- calibration of the model using revealed preference (observed route choice) data.
1 Introduction

1.1 Scope of study

CDM Research was appointed by ARRB on behalf of the Queensland Department of Transport and Main Roads to develop a mid-block level of service (LOS) model for bicycle riders. This study follows from an earlier project examining the “capacity” of shared paths and cycleways\(^1\). That earlier study had the objective of understanding the maximum throughput of a path given specified cyclist and pedestrian demand, directional splits and path width. This maximum throughput represented what was considered to be the limit of comfortable and safe passage of path users.

The present study extends upon that earlier study by developing a model of cyclist level of service that considers not just likelihood of delay, but also the frequency of encountering other path users and, in on-road environments, the frequency of overtaking cars and buses, their speed and the presence of dedicated cycling facilities. The purpose of this model is to provide objective, empirically sound guidance on path width, modal segregation (pedestrians, bicycle riders) and on-road facilities.

The main limitation of this study is that intersections are not considered (except insofar as they influence the frequency of delay). Given that the majority of police-reported cyclist crashes occur at intersections, and that anecdotally riders report a strong willingness to divert around particularly onerous intersections, we would expect a complete picture of route LOS should assign significant weight to these intersection characteristics. However, the scope of this project was limited intentionally to mid-block locations, as it is here that the principle issue of conflict and capacity were deemed most relevant.

1.2 Objectives

The main objective of this study was to assist planners in understanding the relative merits of different types of enroute cycling infrastructure. This included consideration of levels of separation from traffic (e.g. on-road bicycle lanes, protected bicycle lanes and shared paths away from roads) and the main characteristics of roadways (e.g. traffic volume and speed). Furthermore, an understanding of the likely impact of delays on paths would have on discouraging riders (and diverting them onto other routes) was sought. The project outcome was to provide guidance on these issues and a supporting spreadsheet-based model suitable for the non-technical practitioner to be able to quickly test different scenarios.

\(^1\) Sinclair Knight Merz (2010) Bicycle and Pedestrian Capacity Model: North Brisbane Cycleway Investigation, prepared for Queensland Department of Transport and Main Roads.
1.3 Structure of this report

This report is structured as follows:

- Chapter 2 briefly reviews the research on cyclist levels of service, and the application of these models to Queensland.
- Chapter 3 describes the survey methodology adopted to obtain primary data for developing the level of service model.
- Chapter 4 presents results of the survey.
- Chapter 5 describes the estimation and interpretation of the discrete choice model based on the stated preference surveys.
- Chapter 6 briefly describes the spreadsheet implementation of the model, and how it can be used by practitioners.
- Chapter 7 presents a series of sensitivity tests, to illustrate the plausibility of the model.
- Chapter 8 discusses the probabilistic nature of the model, and how this characteristic can be useful in understanding the trade-offs that riders make between different route options.
- Chapter 9 describes a series of typical real-world route planning studies, and how the model could be useful in identifying and prioritising design options.
- Chapter 10 offers two avenues for further work, which may increase the capability of the model and confidence in the model behaviour.
2 Background

2.1 Terminology

2.1.1 Level of service

Level of service is a widely used concept within traffic engineering. In that context it refers to the flow of traffic; LOS A refers to free flow conditions (i.e. no delays) and LOS F refers to severe congestion (i.e. long delays). By this definition LOS can be readily measured as the difference between the observed travel time and that under free flow conditions. LOS is independent of issues such as pavement quality, scenery, road type and so on; it is based purely on the notion that a motorist wishes to travel from A to B as rapidly as possible.

For bicycle riders the LOS will be more complicated for two reasons:

- bicycle riders will perceive their “comfort” as being dependent on far more than just travel time, and
- bicycle riders are a heterogeneous group; preferences for different route types and tolerance for adverse conditions (e.g. busy motor traffic) will differ widely among individuals, and even within individuals across purposes.

We consider here level of service to be analogous to “comfort” or “satisfaction” for bicycle riders. Clearly, this comfort will be strongly affected by – for example – motor vehicle traffic. Furthermore, the way in which riders perceive the presence of motor vehicle traffic will differ between “confident” road riders and more “cautious” riders. Furthermore, just as values of travel time will vary between purposes for motorised modes, so too would we expect riders to assign different tradeoffs between time, distance and en-route facilities depending on their travel purpose (and, indeed, their “mood” more generally).

2.1.2 Capacity

In the earlier Sinclair Knight Merz study for which this project is the basis, the interest was in identifying appropriate path widths to design for future growth in cycling (SKM, 2010). The emphasis was on identifying the maximum practical throughput shared paths and cycleways of given widths could accept. This was referred to as “capacity”. It was assumed that once capacity was reached (or approached) riders would (a) feel increasing dissatisfied, and (b) may be tempted to make unsafe overtaking and hence risk injury to themselves and other path users. The threshold by which capacity was defined was based on an arbitrary tolerance of delay of 5 minute headways (i.e. 12 delays per hour). In effect, this represents a threshold level of service rather than absolute capacity (i.e. maximum flow). As such, the term capacity is not recommended for use in this discussion. Rather, the maximum tolerable demand is instead whatever LOS is deemed to represent a marginal condition. Borrowing from motorist LOS this would usually be the threshold when LOS increases from D to C.
2.2 Previous studies

There have been a number of LOS models developed for measuring mid-block cycling conditions. The main characteristics of these models are summarised in Table 2.1. An extension of the US BLOS (Bicycle Level of Service) model has also been developed for intersections; for simplicity this model is not considered in this discussion.

- Table 2.1: Summary of mid-block LOS models

<table>
<thead>
<tr>
<th></th>
<th>BCI (Bicycle Compatibility Index)</th>
<th>BLOS (Bicycle Level of Service)</th>
<th>Danish BLOS</th>
<th>VicRoads/BNV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>FHWA-RD-98-095</td>
<td>TRR 1578</td>
<td>Trafitec</td>
<td>Unpublished</td>
</tr>
<tr>
<td>Year</td>
<td>1997</td>
<td>1997</td>
<td>2007</td>
<td>2012</td>
</tr>
<tr>
<td>Location</td>
<td>Chapel Hill NC, Olympia WA, Austin TX (USA)</td>
<td>Florida (USA)</td>
<td>Denmark</td>
<td>Victoria</td>
</tr>
<tr>
<td>Usage</td>
<td>FHWA, ≥2 states</td>
<td>≥17 states</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>Methodology</td>
<td>Ranking of stationary video clips (n=202)</td>
<td>Scoring of segments across pre-determined course (n=150)</td>
<td>Scoring of moving video clips table from cyclist perspective (n=407)</td>
<td>Professional judgement</td>
</tr>
<tr>
<td>Parameters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicycle lane</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Shoulder</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kerbside lane width</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Traffic volume</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Heavy vehicles</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>No. of traffic lanes</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Speed limit</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Adjacent land uses</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Presence of parking</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Parking occupancy</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<td>Parking time limit</td>
<td>●</td>
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<td>●</td>
<td>●</td>
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<tr>
<td>Parking lane width</td>
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<td>●</td>
<td></td>
</tr>
<tr>
<td>Pavement condition</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
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</tbody>
</table>
### Level of Service Model for Bicycle Riders

<table>
<thead>
<tr>
<th>BCI (Bicycle Compatibility Index)</th>
<th>BLOS (Bicycle Level of Service)</th>
<th>Danish BLOS</th>
<th>VicRoads/BNV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrians</td>
<td></td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Presence of bus stops</td>
<td></td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Left-turning volumes</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Comment</td>
<td>Stationary roadside video may not be sufficiently realistic</td>
<td>Adopted for use in NCHRP-616 and upcoming 2010 HCM Log-volume is used (linear for BCI)</td>
<td>Most sophisticated modelling specification. Wide range of cyclist facilities (more akin to Queensland situation)</td>
</tr>
</tbody>
</table>

Three methods calibrated their models based on either video clips (BCI, Danish BLOS) of different types of route or actual riding of different routes (BLOS). The latter feels somewhat more reliable, given that videos have a more constrained field of view than the human eye (and more than just visual stimuli are important in a cyclists’ level of comfort). These methods all have in common two significant methodological constraints, however:

- the variables are not always **uncorrelated** (e.g. traffic volume is often related to traffic speed), and
- **extraneous factors** may have an impact of the respondent ratings (e.g. the section of route with a bike path may also have lots of trees and so seem 'more pleasant').

How significant these issues are is unclear without having access to the raw data and videos. Nonetheless, experimental design methods do exist which can avoid (or at least minimise) these problems.

We now review each of the LOS methods in more detail.

#### 2.2.1 Bicycle Safety Index Rating

The Bicycle Safety Index Rating (BSIR) was developed to predict cyclist-motorist crash exposure (Epperson, 1994). The method, developed in Florida (USA), is based on the assertion that LOS is directly correlated with the objective likelihood of crash involvement. It is not clear that the model has been used in practice, and seems to have been superseded by other methods, such as BLOS.

#### 2.2.2 Bicycle Level of Service

The term Bicycle Level of Service (BLOS) has been used by a number of US studies, not always referring to the same underlying model. We refer here to the LOS model developed by Sprinkle Consulting (2007) and subsequently adopted by the US Highway Capacity Manual (HCM). The HCM variant of this model has ten attributes:
• outside lane width,
• bicycle lane width (if any),
• shoulder width (if any),
• proportion of occupied kerbside parking,
• traffic volume,
• traffic speed,
• proportion of heavy vehicles,
• pavement condition,
• presence of a kerb, and
• number of through lanes.

The attributes are weighted and summed to give an overall score (BLOS), which is then mapped to an A-F rating. This model is fairly widely used in the USA, and is likely to continue to be used given that it is now incorporated into the HCM.

### 2.2.3 Danish Bicycle Level of Service

A cyclist level of service model was developed by Trafitec in Denmark, firstly for midblock segments (Jensen 2007) and more recently for intersections (Jensen 2012). Both models were based on a sample of bicycle riders rating videos of different riding conditions. From this data cumulative logit models were estimated and then mapped to LOS ratings by assigning the highest LOS for which 50% or more of respondents indicated they were very satisfied. The model incorporates parameters on motorist volume and speed, kerbside parking, bicycle lane width and the presence of any physical separator. In comparison to the BCI and BLOS models from the USA the Danish model assigns a higher weight to the presence of bicycle facilities. This may reflect (a) the random rather than self-selection of respondents in the Danish study, and (b) the widespread existence of bicycle facilities in Denmark, leading to greater familiarity and comfort among Danes towards separation.

### 2.2.4 Cycling Environment Review Software (CERS)

CERS is a software-based auditing system developed in the UK by TRL. The method is to audit a route based on a number of criteria, each of which are given a subjective score. The routes are then rated based on five criteria, each consisting of a set of sub-criteria – these are listed in Table 2.2. Each criteria is assigned a score from -3 (very poor) to +3 (very good) and then an aggregate score is reported. CERS has not been widely used in Australia, although it has been used on at least one study in Melbourne (Aurecon 2010). The method is based on professional judgement, rather than on surveys of riders.

---

2 [https://www.trlsoftware.co.uk/products/street_auditing/cers](https://www.trlsoftware.co.uk/products/street_auditing/cers)
### Table 2.2: CERS criteria

<table>
<thead>
<tr>
<th>Convenience</th>
<th>Accessibility / safety</th>
<th>Comfort</th>
<th>Attractiveness</th>
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<tr>
<td>Continuity</td>
<td>Intersection conflict points</td>
<td>Effective width</td>
<td>Personal security</td>
</tr>
<tr>
<td>Legibility</td>
<td>Link conflict points</td>
<td>Surface quality</td>
<td>Lighting</td>
</tr>
<tr>
<td>Directness</td>
<td>Traffic volume</td>
<td>Maintenance</td>
<td>Quality of environment</td>
</tr>
<tr>
<td>Accessibility / safety</td>
<td>Traffic proximity</td>
<td>Effort</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Traffic speed</td>
<td></td>
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</tbody>
</table>

#### 2.2.5 Bicycle Environmental Quality Index

The Bicycle Environmental Quality Index (BEQI) was developed by the San Francisco Department of Public Health (SFDPH 2009). It has 21 indicators across five groups (Table 2.3). Two or more surveyors ride the study area and score the route on a survey sheet. The indicators are assigned weights based on a survey of experts and members of a local cycling advocacy group and then summed and normalised to provide a score out of 100.

### Table 2.3: BEQI criteria

<table>
<thead>
<tr>
<th>Intersection safety</th>
<th>Vehicle traffic</th>
<th>Street design</th>
<th>Safety/other</th>
<th>Land use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dashed intersection</td>
<td>Number of vehicle lanes</td>
<td>Presence of marked area for bicycle traffic</td>
<td>Street lighting</td>
<td>Line of site</td>
</tr>
<tr>
<td>bicycle lane</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No turn on red sign</td>
<td>Vehicle speed</td>
<td>Width of bicycle lane</td>
<td>Bicycle lane</td>
<td>Bicycle parking</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicycle pavement treatment + others</td>
<td>Traffic calming measures</td>
<td>Trees</td>
<td>Share the Road signs</td>
<td>Retail use</td>
</tr>
<tr>
<td>Kerbside parking</td>
<td>Connectivity of bicycle network</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic volume</td>
<td>Pavement condition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of heavy vehicles</td>
<td>Driveways</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Topography</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

#### 2.2.6 Cycle Zone Analysis

The Cycle Zone Analysis (CZA) method was developed by Alta Planning + Design for the City of Portland (USA) and has subsequently also been used in Vancouver (Canada).
method is judgmental; first, local professional expertise is used to classify links on a network, followed by advocacy groups and finally public input. The publicly available documentation on the method does not describe the method in detail, but cycle zones are determined from the link characteristics based on:

- quality of the bikeway network,
- difficulty of the barriers,
- density of the roadway network,
- connectivity of the roadway network,
- topography, and
- land use.

These attributes are then assigned a weight, the scores normalised and added to provide a composite overall score. The overall method is illustrated in Figure 2.1. The Bikeway Quality Index is the measure of mid-block LOS and is measured by scoring across a number of attributes such as motorist volumes and speeds and the presence of cycling facilities (shared use paths, signed bicycle routes, wide kerbside shoulders and bicycle lanes).

- **Figure 2.1: Cycle Zone Analysis method (Urban Systems 2012)**
2.2.7 Bicycle Network / VicRoads

The VicRoads Network Operating Plans are a means of prioritising modal access to roads based on location and time of day. These plans use LOS measures for all modes (motorist, public transport (tram/bus), pedestrian, freight and cyclist) to measure performance. In order to measure LOS for bicycle riders a scoring system was developed based on six criteria (Bicycle Network 2012):

- speed and travel time,
- freedom to manoeuvre,
- traffic interruption,
- comfort,
- convenience, and
- safety and risk.

The scoring system assigns scores to both midblocks and intersections. The following infrastructure characteristics are provided with a score:

- on-road bicycle lanes (and their width from 1.0 to 2.0 m),
- profiled line marking ("vibrалine"),
- early start bicycle boxes,
- green surface treatment at unsignalised side streets,
- physically separated by parking (i.e. "Copenhagen" lane),
- traffic speed, and
- kerbside parking.

The scores were developed by professional judgment and were refined after application to a number of test cases.

2.3 Data requirements

While it can be challenging to obtain sufficient high quality data to estimate LOS models from stated or (particularly) revealed preference data, the most difficult challenge is in applying these models in a practical context. Applying any of these models require data on, as a minimum:

- presence of bicycle lanes,
- lane widths,
- traffic volumes,
- heavy vehicle (incl. bus) volumes,
- parking occupancy, and
- speed limits

It is unlikely TMR, or any other road authority, collects data on all of these parameters, nor maintains their data in such a way that this data could be readily obtainable for analysis.
The challenges of developing and then maintaining a database with this range of attributes would be very time consuming and costly. While such data could readily be obtained on a site-by-site basis, it would be difficult to obtain and maintain to a current status for large areas. As such, it is likely that the practical deployment of any LOS model would be limited to a well-defined corridor or area, and would require the collection of primary data within that area.

2.4 Limitations of existing approaches

There are a number of limitations which apply to at least some of the existing LOS models:

- The scores are based entirely on professional judgement, which may or may not accord with the wider riding public (e.g. CERS, Bicycle Network/VicRoads),
- The model coefficients are based on overseas conditions and riders, which may differ markedly from Australian conditions (e.g. BLOS, BCI are both American and the Danish BLOS model), and
- Many of the models do not account for high quality separated on-road infrastructure (i.e. “Copenhagen” lanes) which are the subject of significant policy interest.

2.5 Which model is ‘best’?

Determining which model is best will, of course, depend on the application and the criteria by which one wishes to measure “best”. In this section we provide some commentary on this issue.

Widespread use and experience

The BLOS model is far more widely used in the USA than the BCI model. It is also based on perceptions involving real cycling travel and videos from a cyclist’s perspective (rather than stationary kerbside video in the case of the BCI model). This model forms the basis of the LOS model within the most recent update of the Highway Capacity Manual (HCM), and so has (presumably) been subject to a deal of scrutiny – and is now formally adopted within the USA’s main traffic engineering manual. None of the other models appear to have been adopted this widely, or formally, within their jurisdictions.

Reproducibility

Somenahalli (2008) applied the BCI and BLOS models to a section of Adelaide and found no statistically significant difference between the models. However, the BLOS model was somewhat more sensitive to higher vehicle volumes and speed. However, both models were calibrated to US conditions – which may, or may not, be appropriate to Australia.

Model specification

The Danish model employs the most sophisticated model specification, and includes a number of terms for segregated cycleways which are likely to be useful in an Australian context. The use of a cumulative logit formulation allows for the use of the model in route choice models.
Sampling and bias

Many of the models (including the model developed in this study) rely on a self-selected sample of bicycle riders from the target population. This means there will be very little sample control, and there is a real risk that sample will be skewed relative to the wider riding population. In which way this skew may affect the results cannot be known with certainty, but clearly this is a significant caveat to such methods. The only existing study which appears to have used a genuine random, controlled sampling method was the Danish model. However, the costs of recruitment and retention using this approach are considerable.

Infrastructure types

Many of the models, and particularly those from North America, do not consider high quality infrastructure such as physically protected bicycle lanes. This limitation has been noted elsewhere, and would limit the application of these models in an Australian context where these treatments are of interest.

Model transferability

In all likelihood if an existing LOS model were to be adopted for Queensland use the most likely candidates would be some variation of the US BLOS or Danish BLOS. Two types of tests would be required to determine which, if any, of these two models would be most applicable:

1. Implement the models as-is for a test geography then compare the model outcomes with one another and with expectation.
2. Sensitivity tests should then be undertaken to ensure the models respond in a consistent and plausible manner. These sensitivity tests are very important – if the LOS model is to be used to monitor and evaluate network improvements it must be able to capture adequately such improvements. Sensitivity tests can be readily undertaken in GIS and standard spatial regression methods used to evaluate any changes.

The American studies are based on self-reported perceptions towards video and (in the case of BLOS) riding different types of routes. These locations have very different road infrastructure than Queensland (at least, compared with inner Brisbane) and are now at least 14 years old. Furthermore, when the Danish model was compared with the US models it would found to be more sensitive to the presence of cycling infrastructure. It was hypothesised that this is because Danes are more familiar with such infrastructure than most US cyclists, and so value it more highly. Given the current context in Brisbane (most particularly the inner suburbs) this is likely to be important here also.

How could these models be improved?

There are at least two options for improving these models:
• Develop and field a survey to determine local parameters, and expand to incorporate other parameters of interest (e.g. segregated cycleways, impact of cyclist/pedestrian volumes on LOS).

• Calibrate the model using observed counts (permanent counters, Super Tuesday) and observed route choices (Bicycle Victoria's RiderLop iphone app).

The present study consists of the first of these options.
3 Methodology

3.1 Outline
A detailed online survey asking riders to think in depth about their route choice preferences was developed in order to quantify the different components of level of service. This survey included the presentation of three stated preference (SP) experiments. The sampling process was uncontrolled; respondents were invited to participate through online cycling forums, email lists, social media and word of mouth. TMR staff were also invited to participate through an internal staff email.

3.2 Online survey
The online survey asked a range of questions about existing riding patterns and perceptions towards bicycle facilities, including:

- the respondent’s experience riding bicycles, how often they typically ride and for what purposes,
- information on their most recent riding trip (to use as a basis for the stated preference experiments),
- perceptions towards off-road shared paths and interactions with path users,
- perceptions towards on-road riding and on-road bicycle facilities, and
- demographic information.

The specific questions asked are provided as part of the discussion of the results in Section 4. In addition to these questions, the majority of the survey consisted of three stated preference experiments. These are discussed in the following section.

3.3 Stated preference survey
It has been widely established that riders have a preference for bicycle facilities, both from observed counts of riders and from surveys. What is required for an LOS model is to quantify these preferences in such a way that we can better understand the real-world trade-offs that riders are prepared to make to use these types of facilities.

The approach adopted to quantify these route preferences was the use of stated preference (SP) surveys. These surveys present a series of hypothetical choices to respondents and ask them to choose their preferred option. This survey method is widely used in transport modelling, and has the advantage that the research team can control the presentation of the alternatives in a way that is not possible in the real-world. However, these methods have a significant limitation in that they assume that the way respondents choose between hypothetical alternatives on a survey would be the same as that in practice. This is a major issue with these types of surveys, and is usually addressed by (a) trying to ensure the scenarios are as realistic as possible (partly by basing them on a real trip the respondent had recently undertaken), and (b) calibrating the models with revealed preference (real-
world) choice data. The former approach was taken in this study, and a discussion of the latter approach is presented in Section 10.2.

In this survey, there were three SP experiments and eight scenarios within each experiment was presented to respondents (giving a total of 24 choice sets per respondent). The experiments were:

- Off-road paths (Figure 3.1),
- On-road facilities (Figure 3.2), and
- Off-road vs on-road (Figure 3.3).

These three experiments, and the variables within the experiments, were designed to present as simple but realistic choice sets as possible to respondents. Furthermore, common variables of delay and travel time were used across all three experiments to allow for joint estimation (as discussed in Section 5.3).

- Figure 3.1: Off-road path SP experiment
- **Figure 3.2: On-road facilities SP experiment**

  * Scenario (2): For your Shopping trip, which of the following routes would you prefer to ride?

<table>
<thead>
<tr>
<th>Route A</th>
<th>Route B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time: 60 minutes</td>
<td>Travel time: 66 minutes</td>
</tr>
<tr>
<td>No bicycle lane</td>
<td>No bicycle lane</td>
</tr>
<tr>
<td>No adjacent car parking</td>
<td>No adjacent car parking</td>
</tr>
<tr>
<td>Slow down before overtaking every 10 mins</td>
<td>Slow down before overtaking every 3 mins</td>
</tr>
<tr>
<td>Moderate car traffic</td>
<td>Quiet car traffic</td>
</tr>
<tr>
<td>Light bus traffic</td>
<td>Light bus traffic</td>
</tr>
<tr>
<td>60 km/h speed limit</td>
<td>50 km/h speed limit</td>
</tr>
</tbody>
</table>

  * I would choose:  

  -  

- **Figure 3.3: On-road versus off-road SP experiment**

  * Scenario (1): For your Commuting (i.e. travelling to or from work) trip, which of the following routes would you prefer?

<table>
<thead>
<tr>
<th>On-road</th>
<th>Off-road shared path</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time: 60 minutes</td>
<td>Travel time: 72 minutes</td>
</tr>
<tr>
<td>Bicycle lane with green coloured surface</td>
<td></td>
</tr>
<tr>
<td>Slow down before overtaking every 12 minutes</td>
<td>Slow down to give way to other people every 5 minutes</td>
</tr>
<tr>
<td>Light traffic</td>
<td>Light traffic</td>
</tr>
<tr>
<td>80 km/h speed limit</td>
<td>80 km/h speed limit</td>
</tr>
</tbody>
</table>

  * I would choose:  

  -  

  -  

  [Next >>]
The levels used in the experiments are given in Table 3.1. These levels were selected based on a fractional factorial design, simulation and a final sense check (removal of dominant designs) once the design was folded.

Table 3.1: Variable levels

<table>
<thead>
<tr>
<th>Variable</th>
<th>Experiment</th>
<th>Levels</th>
<th>Self-reported trip time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time</td>
<td>Off-road</td>
<td>80%</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>On-road</td>
<td>80%</td>
<td>Self-reported trip time</td>
</tr>
<tr>
<td></td>
<td>On vs off-road</td>
<td>Self-reported trip time</td>
<td>120%</td>
</tr>
<tr>
<td>Overtake pedestrian</td>
<td>Off-road</td>
<td>3 mins</td>
<td>4 mins</td>
</tr>
<tr>
<td></td>
<td>On-road</td>
<td>3 mins</td>
<td>4 mins</td>
</tr>
<tr>
<td></td>
<td>Pass someone in other direction</td>
<td>3 mins</td>
<td>4 mins</td>
</tr>
<tr>
<td>Delayed by other user</td>
<td>Off-road, on-road, on- vs off-road</td>
<td>3 mins</td>
<td>5 mins</td>
</tr>
<tr>
<td>Traffic speed limit</td>
<td>Off-road</td>
<td>50 km/h</td>
<td>60 km/h</td>
</tr>
<tr>
<td>Traffic volume</td>
<td>Off-road</td>
<td>Light</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>SP only</td>
<td>80 km/h</td>
<td>Heavy</td>
</tr>
<tr>
<td></td>
<td>(every 2 mins)</td>
<td>(every 30 s)</td>
<td>(every 5 s)</td>
</tr>
<tr>
<td>Variable</td>
<td>Experiment</td>
<td>Levels</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>------------</td>
<td>----------------------</td>
<td></td>
</tr>
<tr>
<td>Bus traffic</td>
<td>On-road</td>
<td>Light (every 20 mins)</td>
<td>Moderate (every 10 mins)</td>
</tr>
<tr>
<td>Kerbside parking</td>
<td>On-road</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* Denotes base level in model estimation.
# 4 Survey results

## 4.1 Summary statistics

A total of 729 respondents started the online survey, of which 439 (60%) completed the survey. A further five respondents were removed who completed the survey in less than 15 minutes, leaving a total sample of 443 respondents for analysis.

The most frequently cited reference for finding out about the survey was through bicycle user groups (36%), followed by TMR staff (30%) and through Bicycle Queensland (17%) (Figure 4.1). 37% of respondents did not indicate where they had heard about the survey.

- Figure 4.1: How did you hear about this survey?

![Survey response distribution](image.png)

Almost all respondents had most recently ridden in the past week (Figure 4.2). This result is not surprising given the sampling method and likelihood that more active riders will be more likely to respond than inactive riders.
Figure 4.2: When did you last ride a bicycle?

The sample consists of predominantly regular riders; 67% ride on at least four days in a typical week and a further 25% at least twice a week (Figure 4.3).

Figure 4.3: How often do you ride a bicycle?

Just over a third (36%) of respondents had ridden more than 150 km in the past week, and 41% had ridden 50 to 150 km (Figure 4.4).
Figure 4.4: How many kilometres do you estimate you have ridden in the past week?

Just over half (51%) of respondents had been riding continuously for at least the past ten years, and most of the remainder had been riding continuously for at least the past year (Figure 4.5).

Figure 4.5: How many years of continuous riding experience have you?

Just over two thirds of respondents ride for training or fitness and two thirds (66%) use their bicycle to ride to work (Figure 4.6).
Figure 4.6: Thinking about the times when you ride a bicycle, which of the following are applicable to you? (multi-response)

- I ride for training or fitness, often riding long distances: 77%
- I ride to or from my work: 67%
- I ride for enjoyment, often along quiet streets or through parks: 45%
- I ride around my local area to do my shopping, meet up with friends etc: 29%
- I ride as a way of getting between places which I'm working: 10%
- I ride to or from the place where I study (school, university, TAFE): 3%

n = 434

In order to classify respondents by their frequency and confidence riding bicycles a number of questions were asked about their riding habits. This included asking respondents asking respondents to classify themselves as “cautious” or “confident” when riding on-road. While the frequency and types of riding undertaken by the sample would be suggestive of a generally confident sample of riders, just under half (47%) indicated they were cautious road riders and had a preference for paths or low stress roads (Figure 4.7). This segmentation is used in the route choice models described in Section 5.
Figure 4.7: We would like you to think about the way you ride your bike in the presence of traffic when on-road. Which of the following do you feel best describes your riding style?

4.2 Trip context

It is likely that route preferences will vary by the purpose of journey (as well as on individual characteristics). To provide context to the route choice questions respondents were asked to think about their most recent cycling trip. Just under half (45%) of respondents had most recently ridden for commuting, followed by training/fitness (35%) and for recreation (14%) (Figure 4.8).

Figure 4.8: Now we would like you to think about the most recent trip you made by bicycle. Which of the following best describes the purpose of your trip?
Once very short (less than 5 minutes) and very long (more than 6 hours) trips are removed the average trip duration was 69 minutes (Table 4.1).

**Table 4.1: Most recent trip duration statistics**

<table>
<thead>
<tr>
<th>No. of observations</th>
<th>414</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>5 mins</td>
</tr>
<tr>
<td>Maximum</td>
<td>6 hrs</td>
</tr>
<tr>
<td>Average</td>
<td>69 mins</td>
</tr>
<tr>
<td>Median</td>
<td>60 mins</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>70 mins</td>
</tr>
</tbody>
</table>

Most respondents had ridden a road bike (54%), followed by mountain bikes (22%) (Figure 4.9).

**Figure 4.9: What sort of bicycle did you ride?**

Respondents were asked whether they changed clothes at their destination (to serve as a proxy for “effort”); 70% had a shower and got changed while 16% continued to wear the same clothes (Figure 4.10). The proportion who had a shower increased with riding time, as would be expected. Around 70% of those who rode for over 30 minutes had a shower afterwards, compared to 57% of those who rode for 30 minutes or less (and 50% of those who rode for 15 minutes or less).
Figure 4.10: When you arrived at your destination did you…?

Two thirds of respondents had ridden alone (Figure 4.11), suggesting their route choice preferences were theirs alone. For the remainder, who rode in groups, presumably the choice of route was determined communally.

Figure 4.11: Were you riding alone?

Respondents indicated that on average they spent around 49% of their journey on-road with no bicycle facility, 21% on off-road paths and 18% on on-road bicycle lanes (Figure 4.12).
Unsurprisingly, those cyclists who indicated they were confident road riders (Figure 4.7) rode a larger proportion of their trip on-road without facilities (58% of their travel time, compared with 40% of cautious riders).

Figure 4.12: How much time did you spend on these types of routes?

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Confident</th>
<th>Cautious</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-road, no facility</td>
<td>49%</td>
<td>58%</td>
<td>40%</td>
</tr>
<tr>
<td>On-road bicycle lane</td>
<td>18%</td>
<td>20%</td>
<td>16%</td>
</tr>
<tr>
<td>Off-road path</td>
<td>21%</td>
<td>13%</td>
<td>29%</td>
</tr>
<tr>
<td>Cycleway</td>
<td>12%</td>
<td>8%</td>
<td>16%</td>
</tr>
</tbody>
</table>

\[n = 434\]

4.3 Route choices

The survey asked respondents to rate (e.g. rate from “very uncomfortable” to “very comfortable”) and rank (i.e. order a number of options from most to least preferred) their preferences to particular attributes of off-road paths and on-road conditions for cycling. These ratings and rankings for different types of facilities and conditions are discussed in this section.

4.3.1 Off-road paths

Respondents were asked to rate attributes of shared paths such as surface quality, lighting and the presence of other path users. The results, shown in Figure 4.13, ordered by the proportion indicating “very uncomfortable” suggests that people with dogs, children, lots of intersections and blind corners are the variables which make riders most uncomfortable on paths. Conversely, nice scenery, a low number of cyclists and separation from pedestrians were the most desirable path attributes.
Figure 4.13: When riding on a shared path for <purpose>, how comfortable do you feel in each of the following?

Another approach which produced similar results was to ask respondents to rank the attributes from most to least preferred. This ranking is shown in Figure 4.14, ordered based on the least preferred ranking. The most onerous interactions are similar in both the rating and ranking questions; interactions with unpredictable users (pedestrians with dogs and children).

Figure 4.14: Listed below are some typical interactions on a shared path. Please rank these interactions in order from most preferred (1) to least preferred (10).
Respondents were presented with four sets of physical characteristics of paths as shown in Figure 4.15. The segregated facility was highly approved of (55% of respondents), while the shared path received a more mixed reception (although only 23% disliked riding on such a facility). The presence of vegetation and walls that reduce the effective path width were both seen as discomforting.

- Figure 4.15: In this question we are interested in how the physical characteristics of a path influence your comfort when you are riding for <purpose>. How would you feel riding on these paths?

\[
\begin{array}{cccccc}
\text{Segregated} & \text{Path shared with pedestrians and cyclists with vegetation overgrowing on the edge} & \text{Path shared with pedestrians and cyclists with a wall on one side} \\
5\% & 37\% & 55\% & 5% & 37\% & 35\% & 5\% & 37\% & 35\% & 5\% & 37\% & 35\% & 5\% & 37\% & 35\% & 5\%
\end{array}
\]

- 4.4 Delayed passing

Respondents were then presented with a series of five short (< 20 second) video clips illustrating various interactions that may occur with other path users. Respondents were asked to rate these interactions from one (doesn’t bother me at all) to five (bothers me a lot). The results, ordered by the proportion indicating “doesn’t bother me at all” is shown in Figure 4.16\(^3\). These videos served the dual purpose of introducing the different types of interaction (which are difficult to describe in words or with diagrams or pictures) as well as providing information on preferences towards these interactions.

\(^3\) Around 15% of respondents could not view the YouTube clips on their computer and so were not presented with these questions. It is common to block YouTube access in corporate environments.
The results suggest that riders perceive delays as the most bothersome, followed by overtaking pedestrians travelling in the same direction. These results appear reasonable given that most riders were travelling for transport (so are presumably time sensitive) and overtaking someone travelling in the same direction is more complex than someone travelling in the opposite direction (where both users can see one another). Furthermore, it is consistent with the results reported above that riders feel more discomforted passing other pedestrians than other riders.

Figure 4.16: When riding on a shared path you may experience a number of different interactions with other people. We would like you to look at the following short video clips and rate how you feel about each of these interactions...

Respondents were then asked to rate the regularity of being delayed by interactions with other path users. The regularity with which a rider is delayed was hypothesised to be an important consideration in a cyclist’s perception of convenience, particularly for transport trips. However, it is difficult to directly relate to the regularity of delay and to identify at what regularity it becomes unduly onerous. To partially redress this issue respondents were asked about their perception towards delay in different ways. While somewhat repetitive for respondents, by approaching the problem in different ways greater confidence can be garnered from the result, and the importance of the survey method in influencing the result can be better understood.

Delay was expressed as a headway – e.g. delayed every 5 minutes, as earlier pilot testing indicated this was easier for respondents to understand than a frequency (e.g. 12 delays per hour). Firstly, respondents were asked to rate their tolerance towards delay across six delay headways (presented from least frequent to most frequent). This question type is often referred to as a stated intention (SI). As shown in Figure 4.17, for most individuals delays every 15 minutes or less often were not considered bothersome. Conversely, delays every minute were considered as very bothersome by 62% of respondents.
Figure 4.17: We would now like you to think a little further about how being delayed by other people affects your comfort on shared paths. Think about when you are riding for <purpose>, how would you rate a path where you have to give way before overtaking once every...

Secondly, respondents were asked directly to indicate at what headway they would be “bothered a little” and “bothered a lot” – i.e. they were asked to enter a number of their choice. This type of question is a contingent valuation question.

It is implausible that a respondent would report a lower headway for being bothered a little compared with bothered a lot. For example, if a respondent indicated that being delayed once every 10 minutes bothered them a little then we would expect being delayed at some headway smaller than 10 minutes would bother them a lot. Checks were performed on the data to ensure this was the case; in 67 instances (15%) this was not the case and so these respondents were not considered in this section (as we conclude they had misunderstood the question). Once these cases were excluded the average delay headway to be bothered a little was 11.0 minutes and to be bothered a lot was 4.1 minutes (Table 4.2).

Table 4.2: We would like you to think a little more about how often you would be prepared to be delayed by other people. Please think about when you are riding for an <purpose> trip. How often would you be prepared to be delayed by other people before it...?

<table>
<thead>
<tr>
<th></th>
<th>Bothered you a little</th>
<th>Bothered you a lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>367</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>11.0 mins</td>
<td>4.1 mins</td>
</tr>
<tr>
<td>Median</td>
<td>10.0 mins</td>
<td>3.0 mins</td>
</tr>
<tr>
<td>Standard Dev.</td>
<td>10.0 mins</td>
<td>4.1 mins</td>
</tr>
</tbody>
</table>
In order to compare these two methods the average and median scores from the stated intentions survey were compared with those for the contingent valuation question. These are presented in Figure 4.18. This figure assumes that being “bothered a little” corresponds to a score of three in the stated intention question and “bothered a lot” corresponds to a score of five. The contingent valuation values suggest a greater tolerance to delay (i.e. a higher delay headway) than the stated intention values, which is a result consistent with the research literature (where stated intention questions tend to be more sensitive).

### Figure 4.18: Delayed passing tolerances

![Graph showing delayed passing tolerances](image)

Arbitrary, if one assumes that an acceptable threshold of delay is a score of three (i.e. the midpoint on the scale), then a delay every five (stated intention) to 11 minutes (contingent valuation) represents the threshold. This result has implications for the study of level of service along shared paths in particular, where delayed passing events (at least on busier paths) are likely to be an important factor.

### 4.5 On-road facilities

Respondents were asked a series of questions regarding on-road facilities in much the same way as for off-road paths. When asked to rate a number of on-road lane options the most disliked variables were (not surprisingly) high traffic volumes and speeds, and particularly trucks and buses (Figure 4.19). Conversely, roads with coloured bicycle lanes, standard bicycle lanes and physically separated lanes, were perceived as being comfortable.
Respondents were then asked to rank eight infrastructure options for the most to least preferred. This question revealed a very strong preference for bicycle lanes, and particularly protected lanes – and conversely a dislike of roads without any form of bicycle lane (Figure 4.20).

These results, both individually and collectively, suggest there is a strong preference among riders for bicycle lanes (particularly without kerbside parking) and physically protected bicycle lanes. This holds true even for a sample that appears to be heavily biased towards regular transport cyclists. We would hypothesise that this preference holds even more strongly for infrequent riders and non-riders, both of whom are under-represented in this self-selected sample.
Figure 4.20: We’d like you to think in general about roads with moderate to high volumes of traffic. Please rank the following situations from 1 (most preferred) to 8 (least preferred) on these types of roads.

- No bike lane, no parking
- Wide shoulder, no parking
- No bike lane, adjacent parking
- Bike lane, no parking
- Painted bike lane, adjacent parking
- Bike lane, adjacent parking
- No bike lane, adjacent parking
- Protected bicycle lane

![Graph showing rankings of different road conditions](image-url)
5 Discrete choice model

5.1 Outline
This section describes the estimation of LOS models from the stated preference survey data. A non-mathematical background on the model structure is presented, as well as the model results and interpretation.

5.2 Discrete choice models
Discrete choice models are used where respondents are choosing from a discrete range of options (e.g. to use route A or route B). These models are often based on multinomial logit models. These logit models can be thought of as an extension of classical regression analysis to categorical (rather than continuous) variables. The most important characteristic to note with these models is that they are probabilistic rather than deterministic. If there are two route options A and B, the logit model assigns a probability of selection to each of the two alternatives. For example, if A is more attractive than B it may have a probability of 0.7. This indicates that we expect there to be a 70% chance of an individual selecting route A. To think of this another way, if there were 100 riders choosing between the routes we would expect 70 to choose route A. This probabilistic approach tends to produce more realistic forecasts than deterministic approaches (which would allocate all riders to the preferred route), because of the unobserved attributes of the routes (i.e. those attributes which were not modelled) and variation in the taste preferences between individuals.

5.3 Model estimation
Model estimation is a statistical procedure whereby a specified model (on equation) is fit to a set of data. In its simplest form this procedure is applied to fit linear models to a single independent variable and single dependent variable (e.g. \( y = \beta x \) where \( \beta \) is estimated by linear regression). As we have multiple variables, and a number are categorical, a logit model is used with the stated preference data. These models tend to be more complex to estimate and interpret than simple linear regressions, but have the same basic structure (that is, they consist of an independent variable and one or more dependent variables, at least one of which is categorical).

The SP experiments were setup in such a way that they had two common parameters across all three experiments (delay and travel time). This allowed for the datasets from each experiment to be pooled and jointly estimated using structural parameters (denoted by \( \theta \)) to account for the different error scales within each dataset\(^4\). This method is commonly used within complex discrete choice modelling and allows a more complete model specification to be tested without overwhelming respondents with overly complex choice sets. The model structure is shown in Figure 5.1.

---

\(^4\) The scales are relative to the off-road experiment, so \( \theta_{\text{off-road}} \) is equal to one.
Figure 5.1: Joint estimation model structure

```
Off-road  | On-road  | Facility
---------|---------|---------
 delay    | delay   | delay   
 timepath| timenolane| timenolane
 pedover | timeprotect| timelane
 cyclistover | carpass | timepath
 pass     | buspass | timelane
 speed60  | speed80  | timegreen
 park     |         | protect
```

Each of the model coefficients are described in Table 5.1.

Table 5.1: Model coefficient descriptions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Theta_{onroad}$</td>
<td>none</td>
<td>Error scale of on-road SP relative to off-road SP (values &lt; 1 imply greater unexplained variance)</td>
</tr>
<tr>
<td>$\Theta_{facility}$</td>
<td>none</td>
<td>Error scale of facility SP relative to off-road SP (values &lt; 1 imply greater unexplained variance)</td>
</tr>
<tr>
<td><strong>User interactions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pedover</td>
<td>events/min</td>
<td>Number of pedestrian overtaking events per minute (e.g. overtake 2 pedestrians per minute)</td>
</tr>
<tr>
<td>pass</td>
<td>events/min</td>
<td>Number of cyclist and pedestrian passing/meeting events per minute (e.g. meet 4 path users coming the other way per minute)</td>
</tr>
<tr>
<td>ln(delay)</td>
<td>ln(events/min+1)</td>
<td>Natural logarithm of the number of delayed passing events per minute plus one (e.g. delayed by other path users on average 0.5 times per minute – or once every four minutes). The +1 was used to ensure that events/min&lt;1 had the same sign after the logarithm was applied as those &gt;1.</td>
</tr>
<tr>
<td>buspass</td>
<td>events/mins</td>
<td>Number of bus overtaking events per minute in the nearside traffic lane</td>
</tr>
</tbody>
</table>
### Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>carpass</td>
<td>events/mins</td>
<td>Number of car overtaking events per minute in the nearside traffic lane</td>
</tr>
</tbody>
</table>

### Facility characteristics

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>park</td>
<td>mins</td>
<td>Additional (dis)utility per travel time minute due to kerbside parking</td>
</tr>
<tr>
<td>speed60</td>
<td>mins</td>
<td>Additional (dis)utility per travel time minute of 60 km/h speed limit</td>
</tr>
<tr>
<td>speed80</td>
<td>mins</td>
<td>Additional (dis)utility per travel time minute of 80 km/h speed limit</td>
</tr>
<tr>
<td>time(path)</td>
<td>mins</td>
<td>Travel time on off-road shared path</td>
</tr>
<tr>
<td>time(no lane)</td>
<td>mins</td>
<td>Travel time on-road without bicycle facilities</td>
</tr>
<tr>
<td>time(lane)</td>
<td>mins</td>
<td>Travel time on-road with bicycle lane</td>
</tr>
<tr>
<td>time(protected lane)</td>
<td>mins</td>
<td>Travel time on-road with protected bicycle lane (‘Copenhagen’ lane)</td>
</tr>
</tbody>
</table>

A large number of models were tested for statistical significance, and were estimated using BIOGEME 2.2⁵. Respondents who always selected option A, or always selected option B, within an SP experiment were classed as non-traders and removed from the dataset. This was found to improve the model fit (as measured by the t-values).

## 5.4 Dataset

The model results presented in this section are for a pooled dataset, incorporating both the Queensland survey results and an essentially identical survey conducted in Victoria in 2012. Separate model runs for each state suggested there was no meaningful difference between the samples, and by pooling the data the statistical significance of the estimates improved markedly.

## 5.5 Results

Three models are presented in this section. These models correspond to the full sample of respondents (all riders), confident riders and cautious riders (as self-reported by respondents). The model coefficients and their t-ratios are presented in Table 5.2. The t-ratios are the coefficient divided by the standard error; values of greater than 1.96 indicate the coefficient is statistically significant at the 5% level. It is usual practice to retain variables in the models that have t-ratios greater than 1.96.

The following simplifications were made to the full model specification:

---

⁵ [http://biogeme.epfl.ch/](http://biogeme.epfl.ch/)
• In all models travel time on green coloured bicycle lanes was insignificant. As such, it was combined with the protected bicycle lane parameter; this had no material impact on this parameter as the number of scenarios where green bicycle lanes were presented was low.

• In all models cyclist overtaking events were statistically insignificant – the models do not incorporate this event.

• The speed60 parameter was insignificant for the confident riders model, and so was removed.

• The time on protected bicycle lane parameter was marginally positive and statistically insignificant for cautious riders. A positive time coefficient indicates a positive utility (or preference) for additional travel time. This is contrary to economic theory, where travel time is assumed to have a disutility (that is, travellers seek to minimise their travel time). It is possible that, at least for recreational trips, riders do indeed have a positive preference for travel on high quality lanes. Moreover, it seems plausible that cautious riders would assign very high preferences for physically segregated on-road provision (which in turn would imply a small time parameter). Subsequent sensitivity tests suggested the retention of this parameter marginally improved the plausibility of the model, and so it was retained. However, the insignificance of this parameter means forecasts for protected bicycle lanes with cautious riders should be treated with caution.
Table 5.2: Route choice models (Queensland and Victorian data)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>All riders</th>
<th>Confident riders</th>
<th>Cautious riders</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of observations</td>
<td>13,120</td>
<td>6,633</td>
<td>6,259</td>
</tr>
<tr>
<td>Final Log Likelihood</td>
<td>-7,071.5</td>
<td>-3,610.3</td>
<td>-3,226.8</td>
</tr>
<tr>
<td>Degrees of Freedom</td>
<td>15</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Adjusted $\rho^2$</td>
<td>0.221</td>
<td>0.212</td>
<td>0.253</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>t-ratio</th>
<th>Estimate</th>
<th>t-ratio</th>
<th>Estimate</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural parameters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onroad SP ($\Theta_{onroad}$)</td>
<td>0.668</td>
<td>13.24</td>
<td>0.635</td>
<td>9.97</td>
<td>0.673</td>
<td>8.43</td>
</tr>
<tr>
<td>Facility SP ($\Theta_{facility}$)</td>
<td>0.438</td>
<td>11.84</td>
<td>0.694</td>
<td>8.80</td>
<td>0.364</td>
<td>8.30</td>
</tr>
<tr>
<td>User interactions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pedover</td>
<td>-0.0493</td>
<td>-8.77</td>
<td>-0.0550</td>
<td>-6.76</td>
<td>-0.0437</td>
<td>-5.40</td>
</tr>
<tr>
<td>pass</td>
<td>-0.0231</td>
<td>-4.77</td>
<td>-0.0222</td>
<td>-3.18</td>
<td>-0.0280</td>
<td>-3.94</td>
</tr>
<tr>
<td>delay</td>
<td>-0.0800</td>
<td>-15.13</td>
<td>-0.0722</td>
<td>-10.19</td>
<td>-0.0891</td>
<td>-11.03</td>
</tr>
<tr>
<td>buspass</td>
<td>-0.0464</td>
<td>-7.34</td>
<td>-0.0558</td>
<td>-6.75</td>
<td>-0.0635</td>
<td>-5.68</td>
</tr>
<tr>
<td>carpass</td>
<td>-0.0027</td>
<td>-10.86</td>
<td>-0.0021</td>
<td>-7.34</td>
<td>-0.0037</td>
<td>-5.68</td>
</tr>
<tr>
<td>Facility characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>park (1)</td>
<td>-0.0266</td>
<td>-8.17</td>
<td>-0.0125</td>
<td>-3.77</td>
<td>-0.0351</td>
<td>-6.21</td>
</tr>
<tr>
<td>speed60 (2)</td>
<td>-0.0155</td>
<td>-6.77</td>
<td>n/a</td>
<td></td>
<td>-0.0261</td>
<td>-6.64</td>
</tr>
<tr>
<td>speed80 (2)</td>
<td>-0.0318</td>
<td>-10.61</td>
<td>-0.0197</td>
<td>-6.57</td>
<td>-0.0458</td>
<td>-8.07</td>
</tr>
<tr>
<td>time(path)</td>
<td>-0.0528</td>
<td>-13.79</td>
<td>-0.0621</td>
<td>-11.47</td>
<td>-0.0417</td>
<td>-7.42</td>
</tr>
<tr>
<td>time(no lane)</td>
<td>-0.0628</td>
<td>-12.20</td>
<td>-0.069</td>
<td>-10.70</td>
<td>-0.0696</td>
<td>-7.69</td>
</tr>
<tr>
<td>time(lane)</td>
<td>-0.0175</td>
<td>-4.28</td>
<td>-0.0307</td>
<td>-5.72</td>
<td>-0.0142</td>
<td>-2.29</td>
</tr>
<tr>
<td>time(protected lane)</td>
<td>0.0253</td>
<td>4.70</td>
<td>-0.00635</td>
<td>-1.06</td>
<td>0.0501</td>
<td>5.52</td>
</tr>
</tbody>
</table>

(1) Relative to no kerbside parking
(2) Relative to 50 km/h.

Values in italics are insignificant at the 5% level.

The model summary statistics are described in Table 5.3.
Table 5.3: Model summary statistics

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of observations</td>
<td>The number of observations used in the model estimation. This will be greater than the number of respondent as each respondent will respond to multiple SP scenarios.</td>
</tr>
<tr>
<td>Final Log Likelihood</td>
<td>The value of the log likelihood at convergence. Log likelihood is the sum of the log of the probabilities of the chosen alternatives, and is the function that is maximised during model estimation. The log likelihood is used in comparing the statistical significance of new model coefficients.</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>The number of coefficients estimated in the model.</td>
</tr>
<tr>
<td>Adjusted $\rho^2$</td>
<td>Model fit statistic taking into account the degrees of freedom: $\rho^2 = \frac{LL^* - DOF}{LL^0}$</td>
</tr>
<tr>
<td></td>
<td>Where $LL^*$ is the final log likelihood, $LL^0$ is the constants-only log likelihood and DOF are the model degrees of freedom.</td>
</tr>
</tbody>
</table>

The optimum model specification was determined from a large number of model runs. The judgement of the optimum specification was as follows:

- A measure of overall fit of the model. The objective was to achieve a log likelihood as close to zero as possible while maintaining a parsimonious model. New model coefficients were retained only if the log likelihood was reduced and applying a likelihood ratio test (using the $\chi^2$ statistic).
- The t-ratio of the coefficient; a t-ratio of greater than 1.96 implies 95% confidence that the coefficient is significantly different to zero.
- Plausibility of the coefficients; most particularly that the sign is consistent with expectation and the ratios are plausible.

5.5.1 Interpretation

In interpreting these models the following general principles apply:

- A positive coefficient means the variable has a positive impact on utility; that is, it will increase the likelihood of choosing an alternative with this variable present.
- Conversely, a negative coefficient means the variable has a negative impact on utility; that is, it will decrease the likelihood of choosing an alternative with this variable present.
- Some coefficients are multiplied by continuous variables, such as travel time.

---

6 The t-ratios presented in this table reflect naïve estimates, in that no correction has been made for repeated measurements from the same respondent. This results in an overestimation of the t-ratios. However, as the t-ratios are generally much larger than 1.96 correcting for repeated measurements is unlikely to change the model specification.
Other coefficients are categorical variables, but have been scaled to travel time units and are additive to the base condition. The speed60 and speed80 coefficients are this type of variable; they represent an additional disutility per travel time minute relative to 50 km/h roads. The park coefficient is the other coefficient of this type; if kerbside parking is present there is an additional disutility per travel time minute relative to an equivalent road without kerbside parking.

The models presented in Table 5.2 appear to be behaviourally plausible, as well as being statistically significant. We discuss the meaning of these model coefficients in the following sections.

Structural parameters

The structural parameters account for the different scales of the three different SP experiments. The off-road path experiment is arbitrarily assigned as the base scale (i.e. \( \Theta_{\text{off-road}} = 1 \)), for all models the scales of the on-road and facility SPs are significantly less than one. This implies that the unexplained variance in the on-road and facility SPs is greater than in the off-road SP. This is an expected result, as in some regards the off-road SP is the simplest of the SP experiments, and is presented first (so likely to have more attention paid to it by respondents).

User interactions

The user interaction terms are related to the frequency with which a rider may have to pass or meet other path or road users, and may be delayed (either by other road or path users, or by traffic signals). The unit of measurement in all cases is the number of events per minute. The interpretation of these coefficients is complicated by the transformations applied to the delay parameter, however the following observations can be made:

- \( \text{pedover} \) and \( \text{pass} \) are all linear parameters with negative signs, indicating that as the frequency of these events increases so too does the disutility of that route. This is the expected behaviour; we would expect very busy paths to be perceived less favourably than quieter paths. Furthermore, \( \text{pedover} \) is about twice the magnitude of \( \text{pass} \). This suggests, plausibly, that pedestrian overtaking events are more onerous than meeting events.

- \( \text{Delay} \) has a negative sign, indicating that as the frequency of these events increases so too does the disutility of that route. This is the expected behaviour. Furthermore, \( \text{delay} \) is about 30% to 100% greater than \( \text{pedover} \) (and larger again relative to \( \text{pass} \)). This indicates that delayed passing events are much more onerous than pedestrian overtaking events that do not result in a delay (and meeting events).

---

7 Conversely, it could be argued that as this SP is presented first the variance could be higher as respondents are still 'learning' how the trade-offs work. Our feeling is that this argument is not compelling.

8 This unit of measure makes the parameters independent of travel time. However, it does complicate model interpretation and parameter transformations because it can take positive values less than one (e.g. one event every two minutes would be 0.5 events/min).
The ratio between buspass and carpass events seems plausible; a bus passing event has a disutility 17 to 27 times greater than a car passing event. In other words, a bus overtaking event is perceived similarly to 17 to 27 cars overtaking.

**Facility characteristics**

The facility characteristic terms capture the infrastructure-specific characteristics of each route alternative. The interpretation of these coefficients are as follows:

- The park coefficient represents the additional (dis)utility of riding along a road with kerbside parking compared to a road without kerbside parking. The coefficient is negative, suggesting that riders prefer roads without kerbside parking. This coefficient increases the travel time disutility on roads without bicycle lanes by 42% for the all riders model. Interestingly, the additional disutility is greater for cautious riders (an additional 50%) than for confident riders (18%).

- speed60 and speed80 are both measured relative to a 50 km/h speed limit. Both have a negative sign, indicating that roads with higher speed limits have a higher disutility. That riders would feel less comfortable on higher speed roads is consistent with our expectation. Furthermore, for the confident riders model the speed60 term is insignificant, suggesting these riders do not perceive a difference between roads at 50 and 60 km/h.

- The speed60 and speed80 coefficients are measured in travel time units. As such, they can be directly compared to the travel time coefficients. For the all riders model a 60 km/h speed limit adds 25% to the travel time disutility (relative to a 50 km/h road), and an 80 km/h speed limit adds 51% to the travel time disutility. For cautious riders the disutility is much greater – an additional 38% disutility for 60 km/h roads and 66% for 80 km/h roads.

- The travel time coefficients are all negative (except for protected lanes for cautious riders), implying that riders will be seeking to minimise their travel time (consistent with other transport trips). The disutility of travel time reduces markedly when bicycle facilities are provided on-road; the travel time disutility with bicycle lanes is only 28% of a road without bicycles for all riders. Cautious riders assign greater less disutility to bicycle lanes relative to no lanes (20%) than do confident riders (44%), as we would expect. The reduction in disutility for the protected bicycle lanes are even more marked, suggesting a very strong preference from riders for these facilities (even above conventional bicycle lanes). Confident riders indicated the disutility of protected lanes was only 9% of roads without facilities, and 20% of those with conventional bicycle lanes. However, this coefficient was statistically insignificant. In the cautious rider model time on protected bicycle lanes was positively valued. This is contrary to the expected sign, but may (in combination with the other parameters) reflect a strong preference by cautious riders for this type of facility (which, again is what we would expect).
Table 5.4: Coefficient ratios

<table>
<thead>
<tr>
<th></th>
<th>All riders</th>
<th>Confident riders</th>
<th>Cautious riders</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>User interactions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Traffic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>buspass:carpass</td>
<td>17</td>
<td>27</td>
<td>17</td>
</tr>
<tr>
<td><strong>Facility characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kerbside parking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>park:time(no lane)</td>
<td>0.42</td>
<td>0.18</td>
<td>0.50</td>
</tr>
<tr>
<td>park:time(lane)</td>
<td>1.52</td>
<td>0.41</td>
<td>2.47</td>
</tr>
<tr>
<td><strong>Speed limit</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>speed60:time(no lane)</td>
<td>0.25</td>
<td>n/a</td>
<td>0.38</td>
</tr>
<tr>
<td>speed80:time(no lane)</td>
<td>0.51</td>
<td>0.29</td>
<td>0.66</td>
</tr>
<tr>
<td>speed60:time(lane)</td>
<td>0.89</td>
<td>n/a</td>
<td>1.84</td>
</tr>
<tr>
<td>speed80:time(lane)</td>
<td>1.82</td>
<td>0.64</td>
<td>3.14</td>
</tr>
<tr>
<td><strong>Travel time</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>time(lane):time(nolane)</td>
<td>0.28</td>
<td>0.44</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Note: time(path) is not directly comparable to the other time coefficients because of the presence of the traffic terms in the on-road specification and the user interaction terms in the path specification.

5.6 Model adjustments

The following sections of this report illustrate the implementation and application of the model. This model testing revealed an issue with the user interaction terms on shared paths and cycleways. When these events were very frequent – specifically, when they occurred more often than once every three minutes, they tended to saturate the model. On typical shared paths this threshold is easily reached by the average rider, particularly for the pass term. However, the stated preference experiment only examined ranges of these parameter from passing events from every 15 minutes down to every 3 minutes. The more frequent occurrence of these events was not tested in the survey. It appears the model is overly sensitive to this frequency when it approaches very low values. To redress this issue, and recognising that the survey did not cover this range, frequencies more often than once every 3 minutes were capped to 3 minutes. This resulted in more plausible model behaviours when looking at path capacity (it has no impact on the other facilities).
5.7 LOS mapping

The stated preference model does not output a level of service (LOS). Rather, it provides a generalised cost (or “utility”). This cost is negative, as travelling is seen as a means to an end. The link that has the least negative generalised cost will be preferred by riders.

In order to map this generalised cost to LOS the tolerance to delay was used to link the stated preference model to the contingent valuation questions on delay in the survey (Figure 4.18). This required a number of assumptions:

- the likert scales in the stated intention question map directly to levels of service, namely that:
  - a score of 1 ("Doesn’t bother me at all") equates to LOS A, and
  - a score of 5 ("Bothers me a lot") equates to LOS F,
- the median delay headway is the most appropriate measure of central tendency for this data, and
- the scores represent the thresholds at which LOS changes (e.g. the median delay headway corresponding to a score of 5 corresponds to the threshold between LOS E and F).

This approach gives five delay headway thresholds, each representing the threshold between the six levels of service (A to F). The absolute generalised cost was scaled relative to the median travel time in the survey (20 minutes), and then rebased to the threshold between LOS D and C. This provided changes in normalised utility relative to the thresholds between C and D. These normalised and rebased utilities, for each of the three models are provided in Table 5.5.

<table>
<thead>
<tr>
<th>LOs</th>
<th>Median headway (mins)</th>
<th>All riders</th>
<th>Confident riders</th>
<th>Cautious riders</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>18.96</td>
<td>-1.491</td>
<td>0.25</td>
<td>-1.705</td>
</tr>
<tr>
<td>C</td>
<td>9.47</td>
<td>-1.576</td>
<td>0.17</td>
<td>-1.799</td>
</tr>
<tr>
<td>D</td>
<td>4.73</td>
<td>-1.745</td>
<td>0.00</td>
<td>-1.988</td>
</tr>
<tr>
<td>E</td>
<td>2.36</td>
<td>-2.085</td>
<td>-0.34</td>
<td>-2.366</td>
</tr>
<tr>
<td>F</td>
<td>1.18</td>
<td>-2.763</td>
<td>-1.02</td>
<td>-3.121</td>
</tr>
</tbody>
</table>

Note: each row represents the lower threshold between LOS bands; for example “B” means the threshold where LOS deteriorates from A to B.

This approach allows the generalised cost output from the model to be mapped onto a LOS. However, it is pertinent to note this relationship is nonlinear (Figure 5.2). The effect of this

9 This is one of the most significant challenges in trying to forecast recreation travel (by bicycle or any other mode). In these cases the travel itself is the purpose – travel time is, presumably, positively valued for these types of trips.
transformation is to linearise the utility-LOS relationship. This simplifies the interpretation of the model outputs.

- Figure 5.2: Relative utility and median delay headway by rider type

5.8 Developing the composite route LOS measurement

The model provides a generalised cost (utility) for an individual link. These links need to be homogenous – that is, they cannot change in any characteristic along their length (e.g. traffic volume, width). In practice, almost all bicycle trips would involve the use of differing types of road and path. In turn, these riders are likely to perceive the overall level of service of their trip as a sum of the individual link levels of service. In order to develop this composite route measure of LOS the following procedure was used:

- the generalised cost for each link was calculated,
- the generalised cost for each link was weighted by the travel time, and
- the generalised cost was rescaled to the average travel time (20 minutes) in order to convert to LOS.

This process was simple, but assumes the links are perceived in a purely additive manner. It is not clear this is the case, and the stated preference surveys provide no means of verifying (or refuting) this assumption.
6 Model implementation

The stated choice model has been implemented as an Excel spreadsheet. This implementation provides a user-friendly means of calculating the LOS for links and routes without requiring an understanding of the mechanics of the underlying model. The model consists of three worksheets:

- **Path interactions**: allows an analyst to determine the frequency of delay (and other user interactions) on shared paths and cycleways of specified widths and demand (based on the previous SKM study).
- **Links**: calculates the LOS for a link, and allows the analyst to save the link to a database for further analysis, or incorporation into a route.
- **Routes**: calculate the LOS for a route, consisting of a selection of links obtained from the link database.

Screenshots from each sheet in the spreadsheet are provided in Figure 6.1.

To illustrate the use of the model, consider the following examples:

1. We are interested in the LOS of a shared path, and how it would change if it were widened and/or segregated between modes.
   a. Start with the *Path interactions* worksheet and enter the path width, cyclist and pedestrian demand during the design hour, and the directional split.
   b. If necessary, alter the speeds and standard distributions of the speeds.
   c. Other model parameters, such as clearance distances and proportions in groups can also be adjusted. However, these can be retained as their default values for most situations.
   d. This worksheet outputs the headways of delay, cyclist overtaking events, pedestrian overtaking and meeting events. These values can then be transferred to the *Links* worksheet in the ‘User interactions’ area. In addition, the analyst should select the travel time on the link, the type of link (shared path, road without facilities, road with bicycle lanes or road with protected bicycle lane) and other features of the link.
   e. Select the rider model to apply (all, confident or cautious).
   f. The worksheet will then output the LOS for the link.
   g. The link can be saved for later use by selecting the ‘Add to list’ button to the left of the worksheet.
   h. Scenarios can then be run, and saved as necessary, for different design alternatives (and levels of demand).

2. We are interested in determining the route LOS.
   a. Build each link using the *Links* worksheet, saving each to the link database using the ‘Add to list’ button.
b. Select the Routes worksheet and build the route by selecting the links from the left of the worksheet then clicking on ‘Add to Route’.

c. The route LOS will be displayed next to the route name.

d. If necessary, the route can be saved to the route database to the right of the worksheet.

The spreadsheet makes it quick and easy for the non-technical user to determine the LOS of an existing link or route, and test the likely impact of possible improvements.
- Figure 6.1: Model spreadsheet
  - (a) Path interactions worksheet
  - (b) Links worksheet
(c) Routes worksheet
7 Sensitivity testing

7.1 Outline

The purpose of this section is to demonstrate the plausibility of the model through sensitivity testing. A number of scenarios are presented to illustrate the behaviour of the model. As the model has 14 degrees of freedom it is impossible to describe every possible scenario; instead, the sensitivities described in this section are relative to a “typical” base condition listed in Table 7.1. Unless otherwise stated in the discussion that follows the conditions are as stated in this table.

<table>
<thead>
<tr>
<th>Table 7.1: Base parameters in sensitivity tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>Link type</td>
</tr>
<tr>
<td>On street parking</td>
</tr>
<tr>
<td>Speed limit</td>
</tr>
<tr>
<td>Bus overtaking</td>
</tr>
<tr>
<td>Cars overtaking</td>
</tr>
<tr>
<td>Incur delay</td>
</tr>
</tbody>
</table>

7.2 Motor vehicle interactions

We would expect busier roads to be less attractive to riders, and particularly to cautious riders. Our assumption is that it is motorists travelling in the same direction as the rider, and in the kerbside lane on multilane roads, which is the relevant volume metric in this discussion.

For the base condition (i.e. a road with no dedicated cycling infrastructure) on quiet local streets (around 100 cars per hour) the level of service will border between C and D for the average rider, and be C for confident riders (Figure 7.1). For cautious riders the LOS will be perceived as E (although close to D). That confident riders would perceive local roads without bicycle facilities as more satisfactory than cautious riders is expected. What is perhaps not expected is that these quiet roads would be perceived as having such an unsatisfactory LOS for cautious riders.

The LOS deteriorates most rapidly for cautious riders (as would be expected). The LOS for confident riders deteriorates to E at about 700 cars per hour.
The presence of buses have a more marked impact on LOS. The LOS drops rapidly as the number of buses increases, as shown in Figure 7.2. The rate of deterioration in LOS is marginally greater for cautious riders than confident riders; for the latter group the LOS will be E for low bus volumes and reach F at around 22 buses per hour. For confident riders the road without buses will be C (just) and deteriorate to E at 23 buses per hour (i.e. a bus every 2.6 minutes).
Consider now a road with similar traffic volumes, but with on-road bicycle lanes. A road with 300 cars per hour and no buses will have a LOS of A for both confident and cautious riders if a bicycle lane is present (Figure 7.3). However, as would be expected, the LOS for cautious riders will deteriorate rapidly as the bus volume increase; the LOS will be D at around 25 buses per hour (i.e. a bus every 2.4 minutes) and E at about 40 buses per hour (i.e. a bus every 1.5 minutes). The effect is somewhat less dramatic for confident riders; at 40 buses per hour the confident rider LOS is C (compared to E for cautious riders). This analysis, in comparison to Figure 7.2, illustrates the sensitivity of the model to on-road facilities.
7.3 Delay

The incidence of delay, either due to high volumes on shared paths and cycleways, or perhaps due to intersections on roadways, would be expected to adversely affect level of service. As shown in Figure 7.4 this is indeed the trend. Confident riders are somewhat more sensitive to increasing frequency of delays, as we would expect. For these confident riders the LOS is around B up until around 5 delays per hour. It then deteriorates from C to D at around 11 delays per hour. For cautious riders the situation deteriorates from E to F at around 30 delays per hour.

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10 Care is required in extrapolating delay due to other path/road users to delay due to intersections. The survey only asked about the former, and the latter would be more onerous as they would be likely to require the rider to come to a complete stop.
A similar trend is apparent on other types of bicycle facilities, although the differences between rider groups are less significant (Figure 7.5). Both groups experience a decrease in LOS from C to D at around 13 delays per hour (i.e. a delay every 4.6 minutes).
7.4 Facility type

The purpose for which the LOS is likely to be most useful is in understanding the likely benefits of providing enroute infrastructure for bicycle riders. The sensitivity of the model to infrastructure can be explored in a number of ways.

Firstly, consider the variation in LOS as a function of delay and facility type. This is important in understanding, for example, at what point faster riders using a shared path may decide to shift to an adjacent roadway if the path becomes congested (i.e. there is frequent delay). For all riders this sensitivity is illustrated in Figure 7.6. The effect of delay frequency for the no facility case is as per the discussion in Section 7.3. The effect of providing bicycle facilities of increasing quality is to improve the LOS markedly for all delay frequencies. For example, at a fairly typical delay frequency of 10 delays per hour (i.e. one delay every 6 minutes) the LOS for the no facility case is D, but improves to A with bicycle lanes. For shared paths the LOS would be B under this condition. A similar effect can be observed even under conditions with very regular delays; even when a delay is encountered every two minutes (i.e. 30 delays per hour) the LOS for the bicycle lane option is B and for the shared path E. Protected lanes have a LOS of A for all levels of delay.

Two important conclusions can be drawn from this figure:

- facility provision appears far more important than delay frequency in influencing a riders’ LOS, and
- riders appear to be more tolerant incurring delay on roads with bicycle lanes and protected lanes than on shared paths.
The second of these conclusions is due to the lack of facility-delay interaction terms in the model. Whether this is practically correct is less clear. One possible explanation for this behaviour may be that riders feel they can move into the traffic lane (in the case of standard bicycle lanes) to minimise these delays. Another possible explanation is that riders perceive delays which occur on paths as more significant, as they will often involve pedestrians (which may be seen as more unpredictable than passing other riders). A third possibility is that on paths next to roads riders may be delayed at driveways, whereas on-road motorists entering or leaving driveways are more likely to give way to the rider.

- **Figure 7.6: Sensitivity to delay and facility type (all riders)**

![Figure 7.6: Sensitivity to delay and facility type (all riders)](image)

The all-rider model masks significant differences between cautious and confident riders. Figure 7.7 shows the sensitivity of delays for cautious riders on roads with bicycle lanes and shared paths (protected lanes always have LOS A). For cautious riders delay is perceived more negatively on roads with bicycle lanes than on shared paths. The LOS drops from C to D when delays exceed around 10 per hour (i.e. one delay every 6 minutes) on roads with bicycle lanes and at 12 delays per hour (i.e. one delay every 5 minutes) on shared paths.
For confident riders sensitivity to delay, particularly at low to moderate levels, is greater than for cautious riders. Furthermore, this sensitivity is fairly similar between roads without facilities and shared paths (Figure 7.8). However, delay is relatively unimportant on roads with bicycle lanes, which are perceived favourably even at very high levels of delay.
7.5 Traffic volumes

In this section we consider the effect of traffic volumes on infrastructure preferences. Figure 7.9 shows that the provision of a bicycle lane improves the LOS very markedly for all car volumes\(^{11}\). Protected lanes are not shown in this figure as they achieve LOS A under all conditions\(^{12}\). This means that, for example, a fairly typical collector road with 600 vph during the peak period would have a LOS D where no facility is provided, but this would improve to A for confident riders simply through the provision of a conventional bicycle lane.

\(^{11}\) Note that the vehicle volumes refer only to the direction of travel and the kerbside lane.

\(^{12}\) This may be reasonable; a protected lane means a rider would not expect to have to interact with motorists at all at mid-block locations. Under such conditions the LOS should be reasonably independent of motorist volumes.
The effect of car volumes and on-road facilities is similar in trend to confident riders (Figure 7.10). However, cautious riders generally allocate a lower LOS than confident riders (as would be expected). Cautious riders are highly sensitive to car volumes (more so than confident riders); on roads with no facility cautious riders allocate LOS E at even very low volumes (around 20 cars per hour), although this only deteriorates to F above about 20 cars per hour. This suggests cautious riders are reluctant to ride even on quiet residential streets. However, when dedicated on-road space is provided in the form of bicycle lanes cautious riders give these roads a LOS of C or above for volumes up to about 650 cars per hour. This is somewhat surprising, but reflects the very strong preference of cautious riders to roads with bicycle facilities. Similarly, roads with protected lanes were rated LOS A for all traffic volumes.
7.6 Speed limits

The model shows a decrease in LOS as speed limits increase, as would be expected. At the default urban speed limit of 50 km/h on roads with 300 cars per hour the level of service varies from D to E (Figure 7.11). The speed60 term was insignificant in the model estimation for the confident riders, implying these riders do not perceive a difference between 50 and 60 km/h. However, these riders do react strongly to speed limits of 80 km/h on roads with no bicycle facilities; the LOS drops from D at 60 km/h to E at 80 km/h on roads with the same traffic volumes.

On roads with bicycle lanes and 50 km/h speed limits both rider groups perceive LOS A. At 60 km/h this decreases to D for cautious riders, but remains A for confident riders. At 80 km/h cautious riders perceive such roads to have LOS E and confident riders LOS B. That cautious riders would perceive such roads at 80 km/h to be highly unsatisfactory is as expected. That confident riders would still allocate LOS B on such roads suggests a strong tolerance amongst such riders to high speed traffic as long as they retain their own dedicated riding space (in the form of a bicycle lane).
Figure 7.11: Sensitivity to speed limits (road without bicycle facility)

- All riders
- Confident

Figure 7.12: Sensitivity to speed limits (road with bicycle lanes)

- All riders
- Cautious
- Confident
7.7 Parking

Both confident and cautious riders prefer on-road routes that do not have kerbside parking. Typical roads with bicycle lanes without kerbside parking have an LOS of A for confident riders and LOS B for cautious riders (Figure 7.13). If kerbside parking is present this comfort deteriorates markedly; for cautious riders the LOS decreases to E and for confident riders it decreases to B. The model is thus very sensitive to this parameter (at least for cautious riders), at least for cautious riders, perhaps because of riders’ fears of car dooring crashes.

Figure 7.13: Sensitivity to kerbside parking (roads with bicycle lanes)

7.8 Summary

These sensitivity tests suggest the model is, in general, responding in a plausible way to changes in the parameters. It suggests that cautious riders are far more sensitive to the parameters than confident riders (as we would expect), and that all riders are highly sensitive to the provision of dedicated cycling infrastructure on roadways. It also suggests the all rider model is replicating the behaviour of the confident rider far more so than the cautious rider model. This is an artefact of the model estimation process. The implication of this, in our view, is that the policy maker should consider to whom they are designing a facility (confident or cautious riders), to which minimum LOS they wish to achieve, and to proceed accordingly to analyse the options. There seems little merit in apply the all rider model for most applications.
8  Route choices

8.1  Outline

The model structure is setup in such a way that it can readily be incorporated into a probabilistic route choice model. These models are fairly widely used in transport models. A major advantage of logit models is that they are probabilistic; that is, they assign a likelihood (or probability) to selecting a particular route. This is a behaviour consistent with our expectations; for example, if there were 100 riders who had to choose between two routes we would always expect a proportion to choose one route and the remainder the other route. It would be very rare for all riders to choose one route, as their individual preferences will vary. As such, in discussing route choices it is not an either-or choice but rather a matter of determining the probability of a particular route choice.

In this section we provide simple examples of the forecast demand along completing routes in order to further explore the model sensitivity, and how it can be applied to real-world problems.

8.2  Example 1: Shared path vs roadway

In this example we consider an example of a shared path running directly alongside a busy road. We assume the road and path are directly adjacent such that there is no journey time difference between the alternatives (aside from differences in delay frequency). The question of interest is: as demand increases on the path, at what point do riders start moving across to use the roadway instead? A secondary question is: how is this affected by differing types of rider provision on the competing road? For simplicity we assume the road has the characteristics listed in Figure 8.1. We consider the effects for both confident and cautious riders.

- Figure 8.1: Base road attributes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed limit</td>
<td>60 km/h</td>
</tr>
<tr>
<td>Car volume</td>
<td>800 vph</td>
</tr>
<tr>
<td>Bus volume</td>
<td>6 vph</td>
</tr>
<tr>
<td>Kerbside parking</td>
<td>None</td>
</tr>
<tr>
<td>Delay headway</td>
<td>5 mins</td>
</tr>
</tbody>
</table>

We consider here three scenarios; the road has no bicycle facility, a standard bicycle lane and a high quality protected bicycle lane. For the situation where the road has no bicycle lane when there are only infrequent path delays (5 per hour, or one every 12 minutes) the path is heavily preferred by cautious riders; 86% of riders would prefer the path in this situation (Figure 8.2). However, the preference among confident riders towards the path is considerably lower; only 61% of confident riders would prefer the path in these conditions.
As the frequency of being delayed on the path increases, so the proportion who choose the
road (not surprisingly) increases, but only very gradually. When there are 20 delayed
passing events per hour on the path half of the confident riders would prefer the road.
However, even where there are 40 delays per hour (i.e. a delay every 1.5 minutes) around
73% of cautious riders would still prefer the path. Perhaps more surprisingly, 35% of
confident riders would also still prefer the path. We conclude that the model is insensitive to
path delays where the competing road alternative does not have any cyclist provision\(^{13}\).

- Figure 8.2: Demand forecasts between a shared path and roadway without bicycle facilities

![Demand forecasts between a shared path and roadway without bicycle facilities](image)

Consider now the case where the road has a standard bicycle lane. This increases the
attractiveness of the road among both groups of riders. As shown in Figure 8.3 just over
two thirds of cautious riders prefer the path when there are five delays per hour, and this
decreases to 50% when there are 35 delays per hour. By contrast, confident riders prefer
the road with bicycle lanes, even when there are more delays on the road than the path.
When there are five delays per hour on the path 59% of confident riders will choose the
road. This increases to 70% when delays are very frequent (40 per hour) on the path.
Again, this demonstrates that the model is more sensitive to facility provision than to the
frequency of delay.

\(^{13}\) This result accords with what we know from observation of sites such as Coronation Drive and the Bicentennial
Bikeway; the vast majority of riders choose to use the path, and do so even during peak periods when the path is
busy.
Figure 8.3: Demand forecasts between a shared path and roadway with a bicycle lane

When the road has a physically protected lane there is an even stronger preference for the road, even among cautious riders and when there are more delays in the protected lane than on the path (Figure 8.4). Almost all confident riders prefer the protected bicycle lanes for any delay frequency on the shared path. This preference is less marked for cautious riders; there is only a marginal preference (64%) for the protected bicycle lane when delay frequency is the same on both facilities.

Figure 8.4: Demand forecasts between a shared path and roadway with a protected bicycle lane
This analysis suggests the riders overall are fairly insensitive to frequent path delays, at least when the frequency delay exceeds about 10 to 15 delays per hour (i.e. one every four to six minutes). However, the most significant finding from this sensitivity analysis is to demonstrate the strong preference for bicycle facilities, and particularly higher quality facilities such as protected cycleways on-road and off-road shared paths. This is particularly true for cautious riders.

8.3 Example 2: On-road main road vs quiet street

In this example we consider the scenario where there is a main road and a connected quiet local street alternative (perhaps a bicycle boulevard). We assume the busy road has 800 vph and the quiet streets 50 vph, and that neither route has a cycling facility. Furthermore, we assume that both routes (at least in the initial condition) have a riding time of 20 minutes. The question is: what additional travel time are riders prepared to ride in order to use the quiet street?

As expected, when there is no travel time difference between the two routes between 60 and 75% of riders prefer the quiet street (Figure 8.5). However, this proportion drops off rapidly for both confident and cautious riders as the riding time on the quiet street increases. When the quiet street route takes 4 minutes longer than the busy road (i.e. 24 minutes compared with 20 minutes) then confident riders will be split evenly between the two routes. As expected, cautious riders are prepared to divert further to use the quiet street. When the quiet street takes 9 minutes longer then cautious riders are expected to be evenly split between the routes.

- Figure 8.5: Demand forecasts between a busy road and a quiet street

![Figure 8.5: Demand forecasts between a busy road and a quiet street](image)
8.4 Example 3: On-road vs On-road with bicycle lanes

In this example we consider the scenario where there are two main roads, each with 800 vph. Both are assumed in the base case to require 20 minutes of riding time. However, one of the roads has conventional on-road bicycle lanes. The question is: what additional travel time are riders prepared to ride in order to use the road with bicycle lanes compared to the road with no dedicated facility?

When there is no travel time difference between the two routes between 70 and 75% of riders prefer the road with bicycle lanes (Figure 8.6). However, this proportion drops off rapidly for both confident and cautious riders as the additional riding time on the route with the bicycle lanes increases. When the road with bicycle lanes takes 10 minutes longer than the busy road (i.e. 10 minutes compared with 20 minutes) then both groups of riders will be split evenly between the two routes.

- Figure 8.6: Demand forecasts between a busy road without facilities and a busy road with bicycle lanes

8.5 Example 3: On-road vs On-road with protected bicycle lanes

This scenario is similar to the previous example, except it is now assumed one of the busy roads has protected bicycle lanes. The question is: what additional travel time are riders prepared to ride in order to use the road with protected bicycle lanes compared to the road with no dedicated facility?

When there is no travel time difference between the two routes between 80 and 90% of riders prefer the road with protected bicycle lanes (Figure 8.7). This proportion drops off only gradually for both confident and cautious riders as the additional riding time on the route with the bicycle lanes increases. When the road with protected bicycle lanes takes 23 minutes longer than the busy road (i.e. 43 minutes compared with 20 minutes, or more than
twice as long) then confident riders will be split evenly between the two routes. For cautious riders even when the protected bicycle lane route takes an additional 30 minutes just over 70% of cautious riders will still choose the protected bicycle lane. This result for both confident and cautious riders would suggest that riders are prepared to divert very significant distances in order to use higher quality on-road facilities (compared to roads without any facility).

- Figure 8.7: Demand forecasts between a busy road without facilities and a busy road with a protected bicycle lane

![Graph showing demand forecasts]

- Figure 8.7: Demand forecasts between a busy road without facilities and a busy road with a protected bicycle lane

![Graph showing demand forecasts]
9 Practical examples

9.1 Outline
The purpose of this section is to illustrate the application of the model by example. The links and routes chosen are hypothetical, and serve only to illustrate the application of the model – they are not intended to be realistic examples.

9.2 Link examples
Links are individual sections of road or path; for example, a roadway section between two signalised intersections. It is assumed these links have common characteristics along their length.

9.2.1 Shared use path

Scenario
A shared path in an inner city area is being resurfaced. It is currently 2.5 m wide and carries 400 cyclists in the peak hour (300 in the peak direction, 100 in the contrapeak) and 50 pedestrians (25 in each direction). It is forecast that in five years the path will carry 700 cyclists in the peak hour (525 in the peak direction, 175 in the contrapeak) and 150 pedestrians (75 in each direction).

Objective
What width should the path be rebuilt to in order to achieve a minimum LOS C for the confident rider, and is it most efficient to rebuild the path as a shared path or segregated between modes?

Results
The path interaction calculator, using default inputs, returns a delay headway of 1.9 minutes for a typical rider under current conditions (that is, a rider riding in the peak direction). This, along with the other interaction headways, entered into the link LOS calculator gives a current LOS E. This poor LOS is attributable to the frequent delays the typical rider would experience (i.e. 32 delays per hour).

If the path were rebuilt to its current width of 2.5 m the LOS would deteriorate to F in five years, mainly as a result of the average delay headway decreasing from 1.9 minutes now to every 20 seconds in the future. If instead the path were widened to a 3.0 m shared path the average rider would be delayed once every 1.2 minutes, which would be insufficient to improve LOS beyond F. This would be only marginally better for riders than the do-nothing scenario. Moreover, it would still not achieve the desired LOS C threshold. Widening further to 4.0 m would significantly reduce the delay (now every 16 minutes) and would provide LOS C. However, it would not eliminate the interaction with other riders and pedestrians. The latter contributes much to LOS. As an alternative to widening the path still further (which seems unreasonable given the level of demand), an alternative would be to provide a segregated (or separated cycleway and footpath. If this approach were taken, and a cycleway of 2.5 m provided, the average rider would experience delays every 2.8
minutes. However, the absence of interactions with pedestrians would maintain the LOS at C. In other words, rider would be trading off increased delay frequency against not having to interact with pedestrians. If the cycleway instead was 3.0 m there would be delays every 15 minutes and the LOS would increase to A. The dominant disutility in this configuration is the meeting events with oncoming bicycle riders. The model is insensitive to the lateral clearances between riders; we would expect as the path is widened oncoming riders would give one another more space – which would not be perceived as onerous by either rider. However, the model currently ignores this effect and instead treats all meeting events – whether on a 2.5 m path or 4.0 m path (or wider) as identical. This is a limitation of the model, and would need to be handled qualitatively by the analyst.

9.2.2 Collector road

Scenario
Consider a typical collector road, with 400 cars per hour during the peak and 6 buses per hour. The road currently does not have any bicycle facility, but has kerbside parking and has a 60 km/h speed limit. Riders will incur a delay on average once every 6 minutes.

Objective
Achieve a minimum LOS C for cautious riders by installing some of bicycle facility and/or adjusting the road configuration (i.e. speed limit, kerbside parking).

Results
The road in the base configuration has a LOS F for cautious riders (and D for confident riders). The following three options would all meet the objective of providing LOS C as a minimum to cautious riders:

- installing a standard on-road bicycle lane, removing kerbside parking and reducing the speed limit to 50 km/h would result in LOS A,
- installing a physically protected bicycle lane would result in LOS A, and
- installing a standard on-road bicycle lane and changing traffic conditions such that the peak hour car volume is reduced to 110 vehicles per hour would achieve LOS C.

9.2.3 Arterial road

Scenario
Consider a typical arterial road, with 800 cars per hour during the peak (in the main flow direction, in the kerbside lane) and 20 buses per hour. The road does not currently have any bicycle facility, nor does it have kerbside parking. The speed limit is 80 km/h. Riders will incur a delay on average once every 10 minutes.

Objective
Achieve a minimum LOS C for confident riders.

Results
The road in the base configuration has a LOS E for confident riders (and F for cautious riders). The following treatments would meet the objective of minimum LOS C for confident riders:

- a physically protected bicycle lane would achieve LOS A (note that a standard bicycle lane would only achieve LOS D), or
- a standard on-road bicycle lane and a 60 km/h speed limit.

9.2.4 Kerbside parking

Scenario

A collector road (60 km/h, 300 vph, 3 buses per hour) has a wide kerbside lane where parking is permitted. There is a history of car dooring related crashes along this stretch of road, which we assume takes 20 minutes to ride along. There are opportunities to provide an alternative shared path or protected bicycle lane on a parallel route. Which alternative would encourage most riders to choose the alternative?

Objective

Achieve at least LOS C on the alternative route, and shift at least 50% of confident riders to the other route.

Results

The LOS in the current condition with kerbside parking is D for confident riders. If kerbside parking were removed the LOS would increase to C, meeting the objective. However, if the parking were to be retained the alternatives would, presumably, result in some additional travel time for the rider. Both the shared path and protected bicycle lane alternatives would have LOS A. However, this is only an assessment of the sense of comfort on these routes; it does not judge the relative attractiveness of these alternatives compared to the collector road. If we assume the shared path takes 30 minutes, then we would expect around 48% of riders to divert to this alternative. If instead a protected lane on a parallel road was introduced, and this had a 25 minute travel time, then 74% of riders would divert to that alternative. Naturally, if the difference in travel times were less the proportion diverting would be greater (and vice versa).

9.3 Route examples

Routes are collections of links; each link may differ along the link. This is more akin to a real world scenario where, for example, a rider may travel along a local road, onto a collector road then onto a shared path. The purpose of this section is to illustrate the application of the model to determine a LOS for a complete route. What is excluded from consideration, but would be important in practice, is the influence of intersections on the route LOS.

9.3.1 Road corridor

Scenario

Consider a typical commuter rider (who we consider to be confident) riding to work:
They ride 5 minutes km along a residential road from their home (say 100 vph, 50 km/h speed limit),

They then join a collector road with 500 vph, 4 buses per hour, kerbside parking and a 60 km/h speed limit. The journey on this collector takes 10 minutes.

From the collector road the rider joins an arterial road, where there is a standard bicycle lane, 80 km/h speed limit and no kerbside parking. There are 800 vph and 10 buses per hour. This leg takes 10 minutes.

They then leave the arterial and turn onto a quiet local road (100 vph, 50 km/h speed limit) for the final 5 minutes to their workplace. Kerbside parking is prohibited on this street.

Objective
Determine the LOS for this route, and each link, and then identify options which would improve the route LOS to a minimum of C.

Results
Firstly, we can calculate the link LOS:

- The local street from home has LOS C. This is strongly influenced by the presence of kerbside parking; without parking the LOS would be A.
- The collector road has LOS D. Again, this poor LOS is motivated in part by the presence of kerbside parking; without the parking the LOS would improve to C.
- The arterial road LOS is C; the presence of the bicycle lane (and absence of kerbside parking) are positives but these are compensated by the high traffic volume and, particularly, traffic speed limit (80 km/h). For reference, the same road would have LOS A if the speed limit were 60 km/h. Conversely, without the bicycle lane it would be LOS E with a 80 km/h speed limit and D with a 60 km/h speed limit.
- The local road at the workplace end of the trip is the same as at the home end of the trip, except that kerbside parking is not present. This provides a LOS of A.

The overall LOS for the trip is calculated as D; this is the time weighted average LOS for the route. The following treatments would achieve a route LOS of C:

- If we were to reduce the arterial road speed limit from 80 km/h to 60 km/h this would improve the LOS to A on that link. This intervention of itself would be sufficient to provide a route LOS of C.
- If we were able to install conventional bicycle lanes on the collector road this would increase the LOS on that link from D to A. This would be sufficient to increase the route LOS to C.
- If were able to upgrade the bicycle lanes on the arterial road to protected lanes this would increase the LOS on the arterial road to A, and increase the route LOS to C.
- If it were possible to install a shared path alongside the collector road, and we assume travel times along this shared path are the same as along the road, then the LOS of the path (assuming delays every 10 minutes) would be A, and the route LOS would be C.
This example illustrates the usefulness of the model in identifying potential treatments which would achieve a desired route LOS. Clearly, what it does not do is identify the practicality or cost effectiveness of any particular measure. Nonetheless, it provides the analyst with the opportunity to test different scenarios and to use the outputs to build the case around a particular intervention.

9.3.2 Combined on- and off-road route

Scenario

The previous example involved equal proportions of the travel time on three different types of link (quiet street, collector and arterial roads). This example demonstrates the effect of links of very different lengths.

Imagine a resident of, say, Toowong who rides into the Brisbane CBD. They are a cautious rider. Their current route is as follows:

- 5 minutes on Sylvan Road to the Bicentennial Bikeway – say 300 vph and no buses; there are on-road bicycle lanes and no kerbside parking. The speed limit is 60 km/h.
- 20 minutes on the Bicentennial Bikeway to the CBD. Assume the bikeway is 3.0 m wide\(^{14}\), there are 800 riders in the peak hour (75% heading towards the CBD) and 100 pedestrians (50% heading towards the CBD).
- 4 minutes on Adelaide Street to their workplace, where they have no dedicated cyclist provision and must interact with many buses (100 vph) but relatively few cars (100 vph).

Objective

Determine the current LOS for this route, and each link, and then identify options which would improve the LOS to a minimum of C.

Results

The current link LOS are:

- The LOS on Sylvan Road is A, thanks in large part to the presence of the bicycle lane.
- The demand on the Bicentennial Bikeway will present delays to the rider every 2.4 minutes. They will pass a pedestrian every 20 seconds. This will result in LOS E.
- On Adelaide Street the high volume of buses and the absence of bicycle facilities will result in LOS F.

The overall route LOS will be E, motivated in large part by the short (but very unfavourable) riding along Adelaide Street.

Consider firstly improvements to the Bicentennial Bikeway. Assume, as has been done, the cycleway is widened and segregated between modes. If we assume riders and pedestrians

\(^{14}\) Much of the Bicentennial Bikeway has been widened and segregated between modes. The purpose of this hypothetical example is to illustrate the impact that treatment has had on route LOS.
no longer need to interact on the path then the average time between delay will increase to every 15.5 minutes. The impact will be to improve the LOS to C. Further improvements in LOS would require less interaction between riders. In part, this result seems unduly conservative. However, it may reflect (in part) reticence from cautious riders to have to closely interact with faster riders on cycleways.

The upgrades to the Bicentennial Bikeway would however not improve the route LOS from E. The main issue remains the short but unattractive section of riding along Adelaide Street.

Installing conventional bicycle lanes along Adelaide Street would, presumably, improve conditions marginally for riders. However, cautious riders would continue to perceive riding conditions as poor – LOS would remain F under this condition. However, installing protected bicycle lanes and reducing the speed limit from 60 km/h to 50 km/h would improve the LOS to D. Furthermore, this (in combination with the widened and segregated Bicentennial Bikeway) would improve the route LOS to C.
10 Further work

The purpose of this section is to briefly describe possible avenues for further work.

10.1 Intersection LOS

Intersections clearly play a role in how riders perceive on-road routes. This is particularly true for roundabouts and intersections with turning lanes or slip lanes. Intersections were not part of this study, and so have been ignored in the estimation of link and route LOS. Clearly, the analyst will need to consider the intersections in any practical use of this model – most probably through some qualitative method.

The wide range of intersection designs, and the likely importance of detail design elements within each intersection design in influencing LOS, would complicate the stated preference method used in the present study. However, just as for this mid-block study, it may be possible to use a stated preference method (or some other, simpler, ranking method) to rate generic intersection designs. This could then readily be incorporated into the existing spreadsheet-based model, allowing analysts to build routes of links and intersections.

10.2 Revealed preference calibration

The sensitivity of the model developed in this study appear, in general, to be reasonable. Nonetheless, there may be concern about the high sensitivity to bicycle facilities and, possibly, other attributes such as kerbside parking. That a stated preference model would have high sensitivities is not unexpected, given the hypothetical nature of the scenarios presented to respondents.

A theoretically superior method is to use revealed preference data on route choices. These revealed preferences are what riders actually do rather than what they say they would do (i.e. stated preferences). There are several recent examples of doing this with rider route choice data, such as Portland (USA) and in Switzerland. However, there are three very significant technical difficulties in estimating route choice models from revealed preference data:

- there is limited data on rider route choices,
- there is insufficiently detailed data on link attributes (e.g. traffic volume, presence of kerbside parking) to readily estimate route choice models, and
- there are technical issues associated with the selection of the route choice set and overlapping paths.

We now briefly discuss each of these issues.

Rider route choices

The only information we have on rider route choices comes from surveys or GPS-based methods such as smartphone apps (e.g. RiderLog) or logging and training software such as Strava. Surveys tend to provide weak route information, as they require a rider to trace their route on a map. This route may be simplified compared to their actual route, and there
is the difficulty of converting a line drawn on a paper map to digital form. The latter problem can be rectified by using tablet computers and online maps.

GPS-based methods are probably superior to survey methods, as they are not subject to individual recall or simplification. However, the devices themselves have technical limitations (e.g. canyon effects in city centres) and there is the challenge of cleaning the GPS waypoints and snapping them to a road network. Most critically though is the challenge of ensuring the sample is unbiased. Both RiderLog and software such as Strava are reliant to self-selection; the rider chooses to download and use the app of their own accord. This will invariably result in a bias, probably towards confident riders who are serious about their riding.

These caveats aside, there is undoubtedly strong potential for the use of GPS-based route logging from smartphones. Furthermore, such data is complimentary to permanent counts (which provide counts, but not routes) and may be used in conjunction with Wi-Fi / Bluetooth detection systems to validate and expand these biased samples.

**Link attribute data**

Once a set of route data has been collected the next issue is to identify the characteristics of the chosen route, and of the unchosen routes (see below). The advantage of hypothetical methods is that we can explicit state the link conditions. In revealed preference data we are unlikely to have these characteristics. For example, we may only know traffic volumes on main roads (not local roads) and perhaps only daily counts (rather than the volume at the time when the rider actually used the road). We may also not have complete, or current, knowledge of the presence of bicycle facilities or kerbside parking.

The other technical issue is the correlation between attributes that invariably occur in revealed preference data. For example, there will be correlation between speed limits and traffic volumes – high volume roads are also likely to be higher speed, as they will disproportionately be arterial roads. These correlations introduce problems in estimating route choice models.

**Route choice sets and overlapping paths**

Route choice models require information on the chosen route and on unchosen routes. The problem that commonly arises is that for a typical urban area there will be many thousands of route choices between any two points. Most of these will be highly improbable (e.g. Kangaroo Point to Fortitude Valley via Mount Gravatt) or be minor variations on other routes. There are methods to identify appropriate route choice sets for estimation, but these methods remain subject of considerable academic research.

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15 This is particularly true for Strava, which has a strong following among training riders. There are probably very few riders who use their bicycle to ride to the shops, or with their children, who use Strava. The same is probably also true of RiderLog, but to a somewhat lesser extent given the breadth of the Bicycle Network membership for which this app was designed.

16 Indeed, in theory, one could identify millions of different routes between any two points on a complex road network.
The other issue concerns the many route choices which will vary only marginally from one another. For example, two 10 km routes that are identical except for a 100 m section where a rider may divert down a side street (perhaps to avoid an intersection). These routes are not independent. Handling these routes with overlapping paths in model estimation is, again, a subject of ongoing research.
11 References


