

Finding a bicycle route that offers a high Level of Service in Adelaide

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1 Introduction

Many community planners and policy makers around the world, motivated by a desire to reduce auto use and its related environmental consequences, are embarking on planning measures that would increase the use of non-motorised transportation, mainly, walking and cycling (Krizek, 2004). The Australian government advocates efforts that would promote and establish Australia as a cycle-friendly nation (Austroads, 2005). Many local governments' priorities include encouraging people to cycle by providing cycling infrastructure. Cycling is a good alternative to driving today. Fuel prices are on the rise and people need alternative modes of travel to avoid this problem. Cycling is a low cost, non-polluting, efficient, and healthy way to get to work, school and shopping. Bicycles are a noiseless mode of transportation unlike motor vehicles and residential streets are made safer by reducing the presence of cars. One local cycling organisation (Bicycle SA, 2008a) states that *"cycling can bring changes through improving communities' health, environment, as an economic driver for tourism and as an effective mode of transport, recreation and sport."* Since 2005, the Adelaide City Council has sponsored the Adelaide City Bikes free daily bike hire (up to two hours) program. Tourists, visitors, city workers, students and residents see Adelaide City Bikes as a convenient way to get around the Central Business District (CBD), whether for a business meeting or just catching up with friends. This initiative is geared towards promoting cycling for a cleaner and greener environment (Bicycle SA, 2008b).

The Level of Service (LOS) of a bicycle route is an evaluation of a bicyclist's perceived safety and comfort with respect to motor vehicle traffic while travelling on a roadway corridor. It identifies the quality of service for bicyclists that currently exists within the roadway environment (Shawn *et al.* 1997). Previous studies have reported a number of approaches to derive this level of service; some have developed the Bicycle Level of Service (BLOS) scores and some have developed the Bicycle Compatibility Indices (BCI).

The BCI and BLOS scores can be applied to urban and suburban roadway segments, and have incorporated those variables that bicyclists typically use. BCI and BLOS scores have been used in a number of different applications:

- to assess the "bicycle friendliness" of a roadway (e.g., curb lane width, traffic volume, and vehicle speeds)
- to assist bicyclists with selecting a safe and direct route of travel through their local area and
- to identify gaps or deficiencies in a localised bicycle network.

This study derived LOS indicators for each link in Adelaide and Unley, an adjacent council; and also developed GIS tools for finding the bicycle route with the highest LOS between a given origin and destination. These tools could be used by bicycle coordinators, transportation planners, traffic engineers, and others to evaluate the capability of specific roadways to accommodate both motorists and bicyclists.

2 Bicycle Compatibility Indices (BCI)

The Bicycle Compatibility Index (BCI) was first developed by the University of North Carolina Highway Safety Research Centre for the Federal Highway Research Administration. The BCI is promoted as a procedure for rating the “bicycle compatibility” of a road. The principle variables of lane width, motor vehicle volume and motor vehicle speed, along with the secondary variables are entered into an equation to achieve a number, which is then rated on a linear scale to determine bicycle compatibility from ‘A’ (best) to ‘F’ (worst). The disadvantage of this approach is that it rates individual segments rather than describing the overall suitability of a whole travel route. Intersections and route discontinuities are not always accounted for. The compatibility level of a bicyclist ranges from Extremely High to Extremely Low. Table 1 – Bicycle Compatibility Index (BCI) ranges associated with level of service (LOS) designations and compatibility level qualifiers (FHWA, 1998) illustrates the BCI range and its Compatibility Level. However, in this study, the links are categorised at three levels: low, medium and high.

Table 1 – Bicycle Compatibility Index (BCI) ranges associated with level of service (LOS) designations and compatibility level qualifiers (FHWA, 1998)

<i>LOS</i>	<i>BCI Range</i>	<i>Compatibility Level</i>
A	≤ 1.50	Extremely High
B	1.51 – 2.30	Very High
C	2.31 – 3.40	Moderately High
D	3.41 – 4.40	Moderately Low
E	4.41 – 5.30	Very Low
F	> 5.30	Extremely Low

2.1 Variables in BCI

The BCI reflects the comfort level of a bicyclist on the basis of observed road geometrics, surrounding land use and operational characteristics of roadways. From the above table, it is clear that the lower the BCI value the greater will be the level of comfort a bicyclist experiences.

2.1.1 Number of lanes

The greater the number of vehicular lanes, the higher will be the BCI and lower will be the bicyclist’s comfort.

2.1.2 Lane widths

Wider lanes will result in the lower BCI values and the greater the comfort level of the bicyclist.

2.1.3 Curb lane width

The presence of a wide curb lane lowers the BCI. Additional lane width lowers the BCI. This has a positive impact on the bicyclist level of comfort.

2.1.4 Bike lane width

The presence of a bike lane lowers the BCI. Additional bike lane width lowers the BCI slightly. This has a positive impact on bicyclist comfort.

2.1.5 Paved shoulder width

The presence of a paved shoulder lowers the BCI. Additional paved shoulder width lowers the BCI. This has a positive impact on the bicyclist level of comfort.

2.1.6 Land use adjacent to the roadway

Only two classification types are considered; residential and other.

2.1.7 Speed limit

Higher the speed limit greater the BCI score and lower the comfort level of the bicyclist.

2.1.8 85th percentile speed

The 85th percentile speed is a speed at or below which 85 per cent of the drivers travel. If this data is not available it can be estimated from the trends. Again the higher speed, greater will be the BCI score, which lowers the bicyclist comfort.

2.1.9 AADT (Average Annual Daily Traffic)

The average annual daily traffic count gives the expected traffic volume on any given day. Greater is the AADT, lower will be the BCI which gives lower bicyclist's comfort.

2.1.10 Large percentage of trucks

Greater the percentage of trucks, higher the BCI which will lower the bicyclist's comfort.

2.1.11 Percentage of right turning traffic

Greater the percentage of right turning traffic, higher the BCI which will lower the bicyclist's comfort.

2.1.12 Parking lane

Presence of parking lane increases the BCI and lowers the bicyclist's comfort.

2.1.13 Percentage of parking occupancy

Represents the number of parking spaces filled. Greater is the percentage occupied; lower will be the comfort level of bicyclist.

2.1.14 Parking time limits

Parking turn over is a function of parking time limits. The shorter the time limit the greater will be the frequency of turn over, higher will be the BCI and lower the comfort level of bicyclist.

2.2 BCI formulation

The BCI formulae used for this study is based on Ravada's BCI model (Ravada, 2004), listed below. For the development of the BCI, eight independent variables related to bicyclists' comfort levels were selected along with three variables that should be considered as an adjustment factor. These variables were combined to develop the BCI as follows:

$$BCI = 3.67 - 0.966BL - 0.410BLW - 0.498CLW + 0.002CLV + 0.0004OLV + 0.22SPD + 0.506PKG - 0.264AREA + AF$$

where

BL = Presence of a bicycle lane or paved shoulder > 0.9 metres (No = 0, Yes = 1)

BLW = Bicycle lane width in metres

CLW = Curb lane width in metres

CLV = Curb lane volume – vehicles per hour in one direction

OLV = Other lane(s) volume same direction in vehicles per hour

SPD = 85th percentile speed in km/h

PKG = Presence of parking lane with more than 30% occupancy (No = 0, Yes = 1)

AREA = Type of roadside development (Non-residential = 0, Residential = 1)

AF = Adjustment factor, $AF = Ft + Fp + Fr$

Ft = Adjustment factor for truck volume (ranges from 0 to 0.5)

Fp = Adjustment factor for parking turnover (ranges from 0 to 0.6)

Fr = Adjustment factor for right turning (ranges from 0 to 0.1)

Using the above formulation the BCI is calculate for each link and stored in the GIS database.

3 BLOS Score

Previous literature (Lendis, 1997; Landis *et al.*, 2001; Harkey *et al.*, 1998, 1999; AASHTO, 1999; Rietveld, 2000) used many criteria for finding LOS. Several models have included the presence or width of shoulders and ADT. Some have also included heavy vehicles, pavement conditions and speed limits. This study has shortlisted a number of variables from these studies and selected a few variables that are relevant to the local conditions. The variables are divided into two broad categories pertaining to subjective level of safety and convenience to the cyclists. The variables are classified as level A and level B depending upon their influence on BLOS.

3.1 Level A variables

3.1.1 Traffic Speed

The higher the speed the harder the impact and the more damage done. In some cases speed might also increase the likelihood of overtaking collisions. This variable was categorised into three types i.e. 60 km/h (or more) as the most undesirable speed, 50 km/h to 60 km/h as the median speed and the 40 km/h to 50 km/h of posted speed limit as the most desirable speed.

3.1.2 Volume of traffic

The road links that carry large volumes of cars are also a safety threat to the cyclists. The traffic volume was divided into three categories: high volume (more than 20,000 per day), medium volume (15,000-20,000 per day) and low volume (less than 15,000 per day).

3.1.3 Availability of Bicycle lanes

This variable has been rated high in most of the studies listed in the literature. The presence of a bicycle lane gives a road link a score of 1, and roads without a bicycle lane gains 9 points.

3.2 Level B variables

3.2.1 Bus volume

The bus volume scores are categorised into four types, first category is for the busy bus streets (some streets in the city where buses pass in every 5 minutes or less), second category is for the links that are in 'Go Zones' (15 minutes wait), the third is for the normal bus volumes (i.e. passing every 30 minutes), the fourth category is for the road links that do not have buses. The classes were then awarded scores of 7, 6, 4 and 2 respectively

3.2.2 Number of lanes

This has proved to be an important factor in measuring a BLOS score for each road link. They are also categorised into to four types and awarded scores; a road link with four lanes was awarded a score of two, three lanes a score of four, two lanes a score of six and finally one lane was awarded a score of seven.

3.2.3 Parking

This variable will also have an impact on the bicycle user's safety. Parked vehicles reverse into the road (especially angled parking) posing a safety threat to cyclists. This variable was divided into two categories (parking or no parking). Availability of parking was awarded a score of 7 and links with no parking signs are awarded a score of two.

3.2.4 Intersection impact

Intersections that have three or more legs are categorised as complicated and thus all road links leading to such intersections were categorised as complicated and given high scores (score of seven) and all others are given a score of two.

3.3 BLOS ratings

Table 2 – BLOS ratings Table 2 shows the score based on subjective weighting for each variable. There are two broad criteria of suitability; safety and convenience. The weight of alternatives in each variable is a function of cycling suitability. Using a scale of 1-9, each link in the database was allocated a rating for each variable. The following table summarises all the scores for each criterion.

Table 2 – BLOS ratings

<i>Suitability Criteria</i>	<i>Possible Rating Categories</i>	<i>Points</i>
Speed	60 km/h or more	9
	50 km/h – 60 km/h	6
	40 km/h – 50 km/h	3
Volume of Traffic	High (More than 20 000)	9
	Medium (15000 – 20000)	6
	Low (Less than 15 000)	3
Bike Route	No	9
	Yes	1
Buses	Very Busy	7
	Busy	6
	Normal	4
	No buses	2
Number of Lanes	1	7
	2	6
	3	4
	4	2
Parking	Yes	7
	No	2
Complicated Intersection	Yes	7
	No	2

4 Comparison of BCI and BLOS scores

Bicycle Compatibility Indices and Bicycle Level of Service scores are derived for each link as described above. The links are then classified as low, medium and high LOS (based on BCI and BLOS scores respectively) using the Jenks' classification technique whose classes are based on natural groupings inherent in the data. This method determines the best arrangement of values into classes by iteratively comparing sums of the squared difference between observed values within each class and class means (ArcGIS, 2008). The GIS software (Arc Map) identifies break points by dividing the features into classes whose boundaries are set where there are relatively big jumps in the data values.

Figure 1 and Figure 2 show the LOS category for each link based on BCI and BLOS scores respectively. Table 3 shows the percentage of links that belong to each category of LOS. These results indicate that both methods are not significantly different. However the BLOS model is more sensitive to higher vehicular traffic and speed limits. When comparing these results with Figure 3, it is clear that bicycle lanes enhance the LOS.

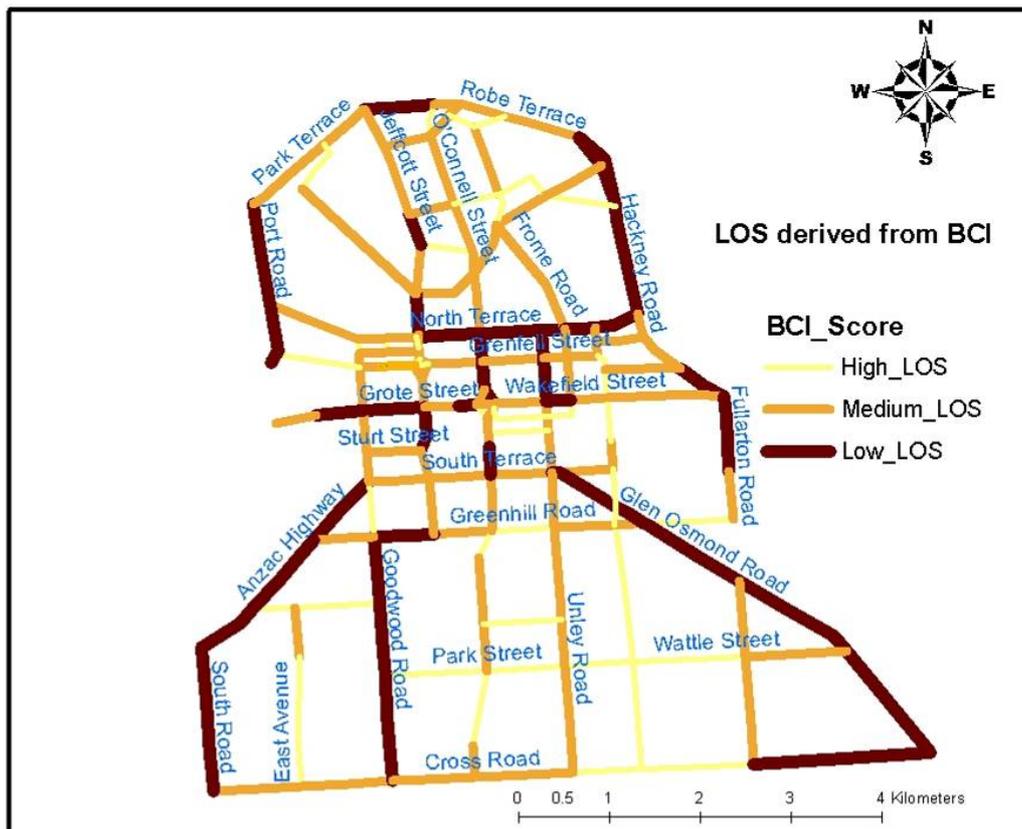


Figure 1 – Bicycle Level of Service derived using Bicycle Compatibility Indices

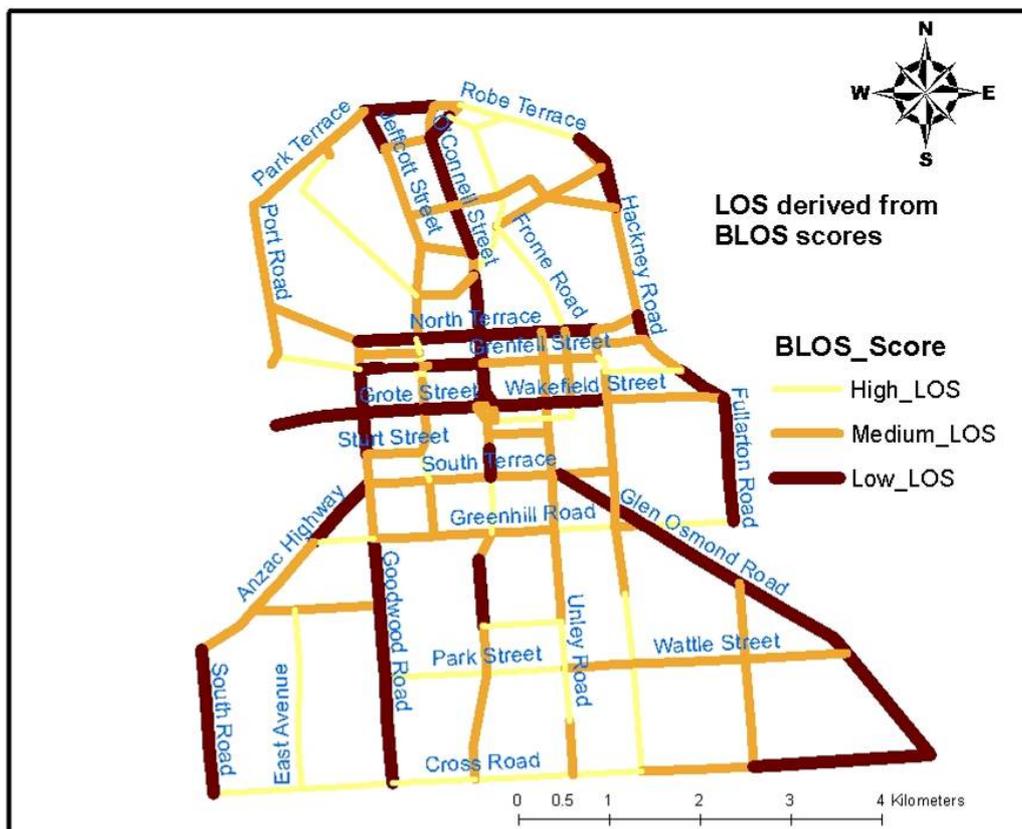


Figure 2 – Bicycle Level of Service derived using BLOS scores

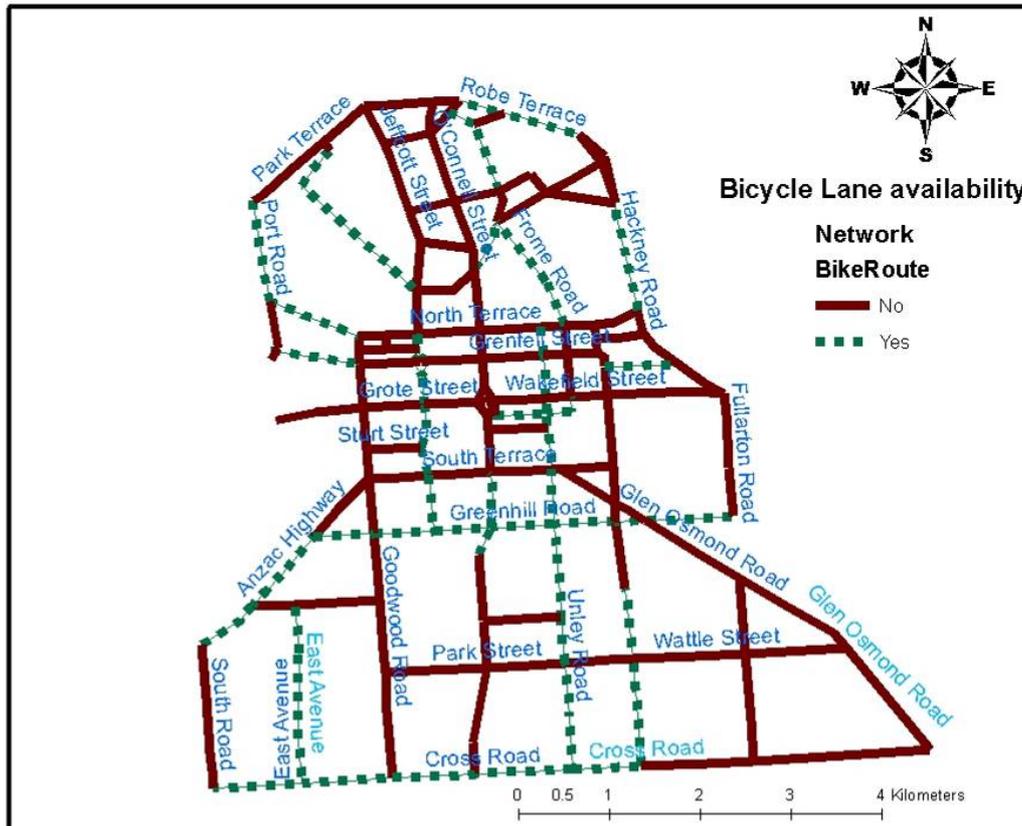


Figure 3 – Presence of cycle lanes

Table 3 – Percentage of links with low, medium and high LOS

LOS derived from BCI	Percentage of Links	LOS derived from BLOS	Percentage of Links
High (0 - 4.14)	25%	High (0 - 34)	24%
Medium (4.14 - 4.87)	50%	Medium (35 - 37)	50%
Low (4.87 - 6.01)	25%	Low (44 - 54)	26%

5 Impedance factors

Once the BLOS scores (or BCI) are calculated for each link, a net BLOS (or BCI) score (S_l) for each link is calculated by summing up the component scores. Subsequently, a generalised impedance factor in the network (C_k) is calculated to maximise the BLOS (or BCI) score for each of the 195 links using the equation below.

$$C_k = \frac{S_{l_{max}}}{S_l} l_k$$

where:

- C_k = Generalised BLOS or BCI impedance factor,
- S_l = Net BLOS score or BCI,
- $S_{l_{max}}$ = Maximum value of S_l for all links, and
- l_k = Length of link k in metres.

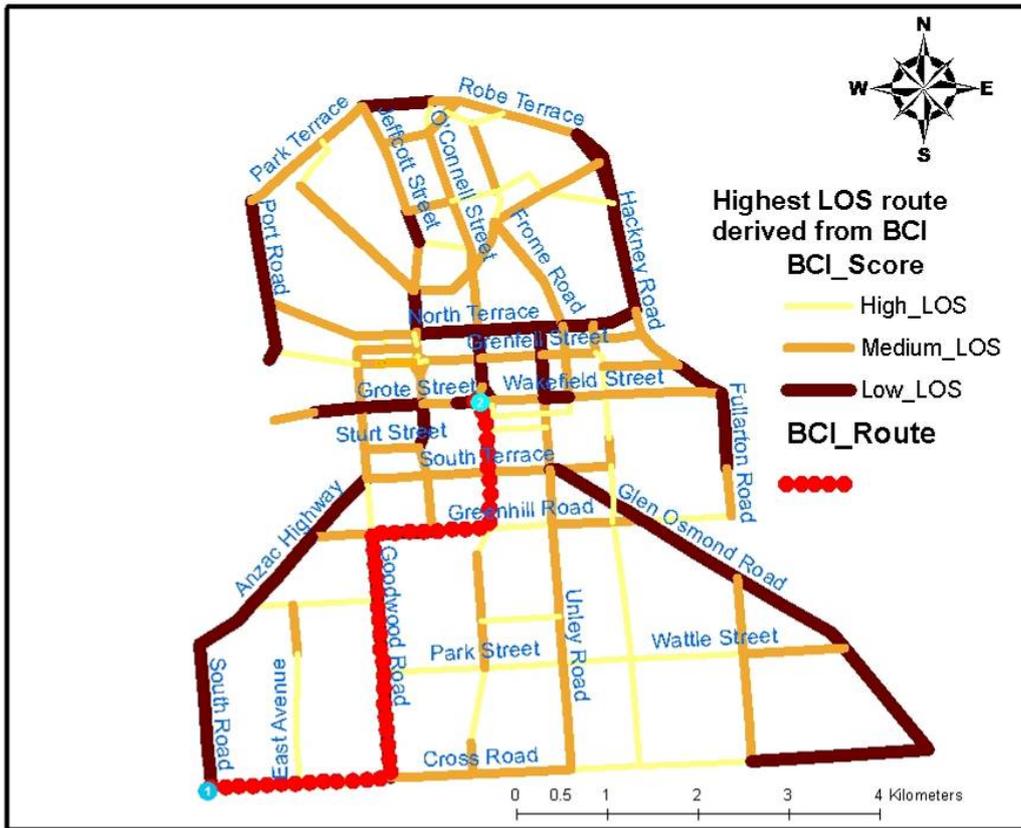


Figure 5 – The bicycle route that has the highest LOS derived from BCI

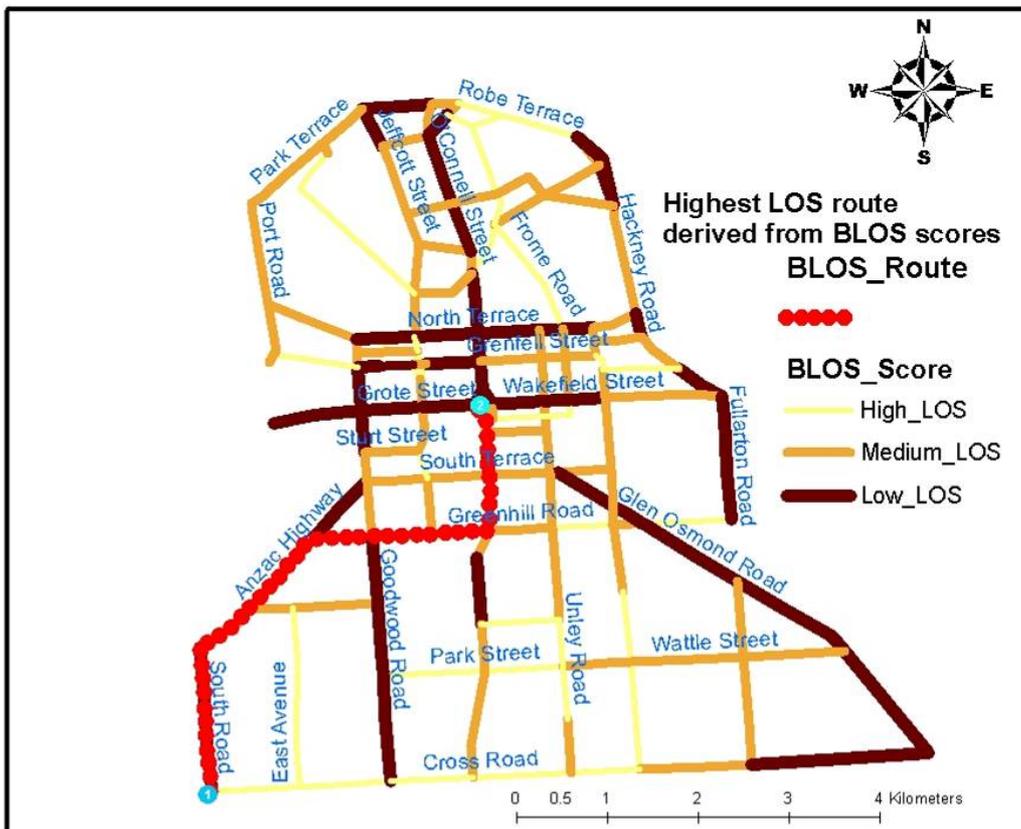


Figure 6 – The bicycle route that has the highest LOS derived from BLOS scores

7 Discussion

Bicycle compatibility measures and level-of-service indicators, measure the suitability of roadways for bicycle travel. The Level of Service (LOS) of a bicycle route is an evaluation of a bicyclist's comfort with respect to motor vehicle traffic while travelling on a roadway corridor. Comfort depends primarily on the perceived level of safety and the rating may be to some degree subjective.

The project identified that most of the roads in the area of the study lack dedicated bicycle lanes and is a matter of concern for the city planners. The BCI and BLOS calculations have shown that presence of bicycle lanes will improve LOS significantly. Cycle networks are traditionally based around the established network of (mostly arterial) roads. However, this study has shown that providing bicycle lanes on secondary roads will have higher impact on LOS than on main roads. For example most of the main roads, such as Anzac Highway, Glen Osmond Road, Unley Road, Goodwood Road, South Road, and Greenhill Road, offer 'low' to 'medium' LOS despite the presence of bicycle lanes. Alternatively the secondary roads that have bicycle lanes, such as East Avenue, Hutt Street, Dutty Street, and War Memorial Drive, offer high LOS. However further studies are needed to support this argument.

It has also shown that GIS can provide a useful platform for identifying a bicycle route which offers a bicycle user the best LOS between a given origin and destination. These tools facilitate the user to choose a safer and comfortable route. The results from this study may also help in identifying the gaps or deficiencies in a localised bicycle network.

The variables that were initially considered but not used include slope, percentage of trucks, types of bicycle lanes and pavement conditions. The road network used in the project was assessed and it was found that generally the slopes are flat and hence this variable is not considered. It was also found that roads in Adelaide are well maintained and felt that pavement conditions would make little difference and hence was not considered.

Both the methods used to derive LOS showed similar results. However, it would be interesting to correlate this information with the actual perception of local bicycle users. The author is currently conducting a survey to develop a model to measure the influence of road geometrics and traffic conditions on cyclists' perception of level of service offered at each intersection. Thus, the ongoing survey will make an attempt to address the limitations listed in this research paper.

Acknowledgments

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