DO CYCLE ROUTES PAY?

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Abstract
Historically the demand for cycling has been waning, implicitly suggesting the potential economic value of the cycle industry has been diminishing. However over the past decade both national and local transport policies have recognised the potential benefits of cycling in achieving environmental benefits as well as health benefits. Moreover there is a well defined role for cycle routes and facilities within the tourist industry which adds direct value to the economy. As such the demand for cycling has been reinvigorated through the government sustainable transport agenda which is advocating consistent growth within the UK leaving a latent demand that needs to be realised. Moreover, public health concerns have reinforced this change in policy emphasis, not least because of concerns about low levels of population physical activity and weight gain.

Unfortunately sustainable transport, including walking and cycling, has been and continues to be a point of contention for developers and planners alike with respect to infrastructure improvements. One of the most difficult aspects hindering their uptake is the complexity of determining their fiscal valuation – exactly how much is a cycle route worth? i.e. what is the market value for services provided?

With a view to developing a framework to underpin potential investment decisions, this study applies core economic principals and analysis methods to derive the potential value, and hence profitability, of cycle routes using an empirical example from Scotland. Previous work has looked into the recreational value of cycle routes in Scotland using the Glentress mountain biking facility and the present work provides an extension to this using the national cycling network. The reason for doing so is to evaluate the consumer value of existing facilities in order to (i) test the case for further network expansion and (ii) elucidate the extent of realisable business expansion potential along existing routes.

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1. Introduction

This paper highlights the practical value of conducting simple travel cost valuation based analysis of consumer surplus to derive the value of cycle routes. As far as is known only two such examples exist (Fix et al, 2000 and Moran et al, 2006) in the literature, both of which focus on recreational routes. This will, therefore, be an innovative attempt to value a cycle route used as a traffic corridor for commuting purposes rather than simply for recreational purposes, although it can and does also get used for such purposes.

Understanding the potential valuation of such routes is crucial from a development perspective, particularly with increased pressure to promote sustainable transport solutions that meet not only environmental policy objectives but also objectives relating to noise, safety, health etc. However the benefits/value of cycling are far less tangible than for other modes of transport and hence more difficult to feature into investment decisions which are often reliant upon monetary valuation of schemes. The method applied in this paper provides one approach to valuing such services which can help clarify (i) the indicative welfare gains that a local authority can provide to its constituency members and (ii) the potential business viability of a cycle route for private sector investors.

The site location, The Forth Road Bridge, was opened for use on 4 September 1964 and forms the principal corridor of vehicle movement between south-east and north-east Scotland. At 1816m long the dual carriageway bridge carried around 2.5 million motor vehicles in its first year, this annual figure has risen steadily over time to around 24 million vehicles in 2006\(^3\).

Figure 1, Bridge location and survey site

When constructed, during an era where predict and provide was very much the paradigm for transport infrastructure (see for example Berry, 1960), the developers had the foresight to incorporate cycle paths tracks into the design. The paths are separated from the road traffic and lie outwith the main road deck.\(^4\) Since construction the bridge

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\(^3\) See [http://www.feta.gov.uk/index.php?option=com_content&task=view&id=33&Itemid=93](http://www.feta.gov.uk/index.php?option=com_content&task=view&id=33&Itemid=93)

\(^4\) These paths are 2.74m wide for the duration, alongside these are parallel footways. 1.83m wide, segregation is via a solid white painted line.
has continued to be maintained and operated, currently by the Forth Estuary Transport Authority (FETA), with a joint board formed by representative of City of Edinburgh Council, Fife Council, Perth & Kinross Council, and West Lothian Council.

The relatively high quality of the cycling provision on the bridge is a testament to the period when the bridge was built, when at the time bicycle use in the UK was much higher (see Tolley (2003) for further discussion), and the local shipyards and docks clustered around the base of the bridge were far bigger employers, and consequently the large residential areas to the north and south of the bridge would have housed many of the workers in these industries. From the port of Rosyth a North Sea passenger ferry to Zebbrugge still operates, carrying large volumes of tourist traffic, this service is scheduled to cease operating in September 2008.

For local cyclists the bridge is a crucial link between the northern Edinburgh suburbs and wider residential communities in West Fife. These include the City of Dunfermline 3km north-east with a population of 45000, Inverkeithing 1.5 km east and Dalgety Bay 4km east. Adjacent to the feeder ramps on the northern landfall is also located the Park and Choose facility at Ferrytoll. This can store 1040 cars, and 17 bicycles in lockers it also has bus links to the local rail stations, direct bus services to Edinburgh and offers routes to surrounding cities. The cycle track on the bridge forms part of Sustrans UK National Cycle Network Route 1 (NCN), which begins in the Shetland Isles and runs the length of the UK to Dover, it also forms part of the North Sea Cycle Route, (another leisure cycle route aimed at tourists), and consequently attracts a large amount of cycle tourist traffic.

The physical cycle provision on the bridge, in terms of space and surface quality is not matched by that afforded to the approaches at either side of the bridge. These are made up of combinations of backstreet on-highway routes, or former footways re-designated for shared use by pedestrian and cyclists. This is a common feature of the NCN. This variable quality on the NCN sections leads to cyclists on different types of machine making very different route choices once away from the bridge approach itself.

Some choose to continue on the NCN route alignments, until their ultimate destination leads them onto the road network, others may join the main road network once they leave the bridge approach routes. This may be as a result of the type of machine used; fast, road-racing bicycles are not well suited to the rougher surfaced sections of the LCN routes. While others may join the road network to avoid the necessary reduction in speed that is frequently a requirement of the NCN due to the interaction with pedestrians, therefore avoiding the time penalty that comes with using these facilities.

Nevertheless all of these cyclists must either travel over the bridge, or incur a diversion via the next nearest crossing 16 miles west at Kincardine, making many of them a captive market.

The order of the paper is as follows: The next section discusses the methodology applied, while the following section presents the data used. Section 4 presents the results of the analysis, including discussion as to the potential value of the cycle route itself. Finally, Section 5 concludes the paper with a discussion of the research findings and potential future avenues for research.

2. Methodology

This section details the methodology used to obtain the consumer valuation, proceeding with a brief overview of the relevant theory and supplemented with a short discussion on how it is implemented empirically. The analysis is built upon an analysis of the average consumer surplus for the sample of individuals surveyed, see Figure 1
for a graphical illustration of consumer surplus in the context of a standard supply and demand framework.

Following previous literature (in particular Fix et al, 2000 and Moran et al, 2000) there are three principle econometric techniques which have been applied to do this, which given the variables outlined in the data section are as follows;

**Ordinary Least Squares (OLS) regression;**

\[ \text{Trips}_i = c + \beta_{TC} TC + \beta_{Income} Income + \beta_{Gender} Gender + \beta_{Age} Age + \beta_{Ed} Education \]

**Poisson regression;**

\[ \text{Trips}_i = e^{(c + \beta_{TC} TC + \beta_{Income} Income + \beta_{Gender} Gender + \beta_{Age} Age + \beta_{Ed} Education)} \]

**Negative binomial regression;**

\[ \text{Trips}_i = 1 + ae^{(c + \beta_{TC} TC + \beta_{Income} Income + \beta_{Gender} Gender + \beta_{Age} Age + \beta_{Ed} Education)} \]

Where TC is the travel cost. Each of the models uses the same set of explanatory variables however they are based upon a different estimation method. The OLS regression is the first and most simple method used, however its estimator is built upon an assumption of an unbounded continuous normal distribution. The normal distribution is not well suited to modelling count data as it is unlikely that deviations from the mean are likely to be symmetric. As a result modellers chose to base the estimator on a poisson distribution, leading to the poisson regression, which has an asymmetric distribution about the mean and is more reflective of count type data. The method was further developed to account for the possibility that the poisson distribution might be ‘overdispersed’ leading to the negative binomial regression. As such the pure poisson regression could be considered a restricted version of the negative binomial. Truncated versions of the poisson and negative binomial regressions are proposed in the literature, see Fix et al (2000), however when applied to the present data the results remained unchanged, hence these are not discussed further here.

Due to small sample sizes and the potential problems this may cause with respect to both the accuracy of the coefficients and the resulting inference a bootstrap algorithm was used to estimate the models. The bootstrap algorithm (see for example Efron and Tibshirani, 1993) is implemented for this paper as follows: Draw randomly, with replacement, a data matrix from the original sample of data with the same dimensions as the original data (e.g. the same number of variables and observations). This produces a new dataset with the same fundamental dimension, albeit with different relationships. These different relationships are used to represent alternative versions of reality that may have feasibly occurred given the sample characteristics. Using this sample estimate the model and record the coefficients returned. Repeat this process a large number of times recording the coefficient values for each replication. In this instance 10,000 replications are done. After all the replications are run the coefficients are then used to determine the coefficient distributions, which may or may not be normal, and can subsequently be used to determine the accuracy of the results. The achieved significance value approach defined by Efron and Tibshirani (1993) is one approach that can be used to place exact p-values on the results, though as Killian explains there is an ongoing debate as to how to control for bias. In order to avoid these potential concerns we simply present the full and complete distributions to allow the reader to come to their own conclusion. However, for convenience we also indicate the variables which are highly significant (p-value<0.05) for the preferred models.

Following Moran et al (2006) travel cost is determined as follows;

\[ TC = (C \times D) + T + F + A + B + (H \times 2) \times (0.43 \times W) \]
Where \( TC = (\text{perceived}) \text{ travel cost} \), \( C = \text{the cost of car rental} \), \( D = \text{the number of days rented} \), \( T = \text{ticket costs for public transport} \), \( F = (\text{individual share of}) \text{ fuel cost} \), \( A = \text{the cost of accommodation} \), \( B = \text{cost of bike hire} \), \( H = \text{time spent travelling to the start of the journey} \) and \( W = \text{wage rate} \). Fix et al. (2000) discuss the potential role of endogeneity in travel costs within the context of the travel cost method on the premise that travel choices may be some function of the trip itself. In the present study it has been assumed that all costs are exogenous however this assumption.

\[ \text{Figure 2: Consumer surplus and the supply and demand relationship.} \]

The data used for the study were collected via surveys which were carried out, the first on Sat 2nd August 2008 between 12.00 and 3pm, the second on Tuesday 5th August between 7 am and 10 am (refer to Figure 1) for the location the surveys were undertaken. For the second survey notices were posted at the survey site alerting cyclists to the presence of the interviewers on the following Tuesday morning and requesting the cyclists to build time into their commute to allow them to take part in the process.

On both days the weather conditions were cooler than seasonally expected, in part an effect created by the chosen location site. This was at the northern bridgehead where it enters a cutting into the surrounding hillside, the geography tending to create a consistent breeze. Data collection was via surveys carried out using simple random sampling methodology, with two interviewers conducting face-to-face surveys. A number of surveys were offered out to members of the public who were not keen to stop, these were posted back in response paid envelopes, of all the potential respondents requested to take part in the surveys only three actually refused to take part. The sample method choice, while unstructured was appropriate for the situation and purpose of the exercise. The surveys were carried out with the permission of FETA. See Caussade et al. (2005) for an overview of stated choice and willingness to pay methods as well as the impacts of analyst’s choices when using survey design mechanisms.

\[ \text{5 Moran et al. (2006) based fuel cost on distance (measured via a web-based tool), however we chose to retain perceived costs on the basis that (i) Moran et al. (2006) claim these both had a high correlation and (ii) people base behaviours on expectations as they often do not have complete knowledge of the specific cost of any given journey,} \]
Anecdotally, it was interesting to note just how keen most respondents were to be sampled. This in itself may be indicative of the social status and wellbeing that cycle as a travel choice is related to with users.

3. Data

Table 1: Descriptive statistics – overall data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trips</td>
<td>184.34</td>
<td>329</td>
<td>1</td>
<td>110.09</td>
</tr>
<tr>
<td>Income</td>
<td>35791.67</td>
<td>50000+</td>
<td>12500</td>
<td>11468.92</td>
</tr>
<tr>
<td>Age</td>
<td>41.18</td>
<td>58</td>
<td>22</td>
<td>7.74</td>
</tr>
<tr>
<td>Education</td>
<td>3.6</td>
<td>5</td>
<td>0</td>
<td>0.99</td>
</tr>
<tr>
<td>Skill</td>
<td>2.9</td>
<td>4</td>
<td>1</td>
<td>0.70</td>
</tr>
<tr>
<td>Travel cost</td>
<td>35.523</td>
<td>412.53</td>
<td>0</td>
<td>97.86</td>
</tr>
<tr>
<td>Gender</td>
<td>0.9</td>
<td>1</td>
<td>0</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Number of observations = 60 n.b. the full sample included 67 respondents, though some were dropped (using casewise deletion) due to data attrition. See Broadstock et al (2007) for a discussion on the use of casewise deletion and other methods to deal with attrition.

Education 1 = primary, 5 = vocational n.b. vocational was ranked above degree as these respondents include lawyers and similar vocational qualifications largely. In the empirical stage a dummy variable will be used to control for these qualifications as it is not entirely justified that they should be either higher or lower than degree standard.

Skill 1 = Beginner, 4 = Expert
Gender 1 = Male

The key descriptive statistics for the data are presented in Table 1 and are supported by a number of plots given in Table 2. Cumulatively it is seen that the sample of respondents have quite interesting/unique characteristics. The average wage of those questioned was well above the national average, and given that the upper category response for this question was simply a £50,000+ per annum, for which there were a number of respondents, then the actual average will be even higher still. This results in high travel costs as the value of time for such individuals is much higher due to the opportunity cost of time spent in any one activity relative to work time. It is also seen that there are a large number of respondents working more than 40 hours per week, which may in itself be a precursor to the above average wages.

The average age was higher than was expected a-priori at 41 and is arguably reflective of the notion that some of the more affluent members of the community (which are normally those who have had time to forge a successful career) place value in living on the periphery of Edinburgh rather than being centrally located. A further surprise finding was the small proportion of route users that were female. We did not foresee any fundamental reason why there would or should be more male than female users, however the observed sample was nearly entirely male.

Table 2: Graphical analysis of selected survey results

| Skill | Income |
4. Results

The results of the empirical modelling are provided in Table 3.

Table 3: Results of analysis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Commute OLS</th>
<th>Poisson</th>
<th>Negative binomial</th>
<th>Leisure OLS</th>
<th>Poisson</th>
<th>Negative binomial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-23.519</td>
<td>3.861</td>
<td>4.043*</td>
<td>226.789</td>
<td>5.422*</td>
<td>5.494</td>
</tr>
<tr>
<td>Travel cost, £</td>
<td>-0.587</td>
<td>-0.017</td>
<td>-0.017*</td>
<td>0.831</td>
<td>0.005</td>
<td>0.004</td>
</tr>
<tr>
<td>Income</td>
<td>-0.005</td>
<td>-0.000</td>
<td>-0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Gender</td>
<td>134.973</td>
<td>1.081</td>
<td>1.281*</td>
<td>76.718</td>
<td>0.417*</td>
<td>0.419</td>
</tr>
<tr>
<td>Skill</td>
<td>39.983</td>
<td>-0.417</td>
<td>-0.553</td>
<td>43.028</td>
<td>0.205*</td>
<td>0.201</td>
</tr>
<tr>
<td>Age</td>
<td>7.241</td>
<td>0.118</td>
<td>0.059*</td>
<td>-3.578</td>
<td>-0.019*</td>
<td>-0.019</td>
</tr>
<tr>
<td>Education</td>
<td>23.652</td>
<td>3.86</td>
<td>0.056</td>
<td>-24.359</td>
<td>-0.117*</td>
<td>-0.122</td>
</tr>
<tr>
<td>$\alpha$ (dispersion)</td>
<td>n/a</td>
<td>n/a</td>
<td>-1.342</td>
<td>n/a</td>
<td>n/a</td>
<td>-2.522</td>
</tr>
</tbody>
</table>

Notes:
(i) Coefficients in italic and marked with a * are significant at the 5% level
(ii) The coefficients reported in this table are the mean-value bias corrected coefficients emanating from the bootstrap model run with 10,000 replications.
(iii) Full empirical distributions for the coefficients of the preferred models are provided at the end of the paper.

The results given in Table 3 consistently support the underlying demand relationship in so far as the estimated coefficients on the travel cost variable are all negative and
highly significant. The other factors featured within the model are essentially control factors, and as such there significance or insignificance is relatively limited importance. However it is surprising how un-robust the estimated coefficients are across the estimation procedures applied.

In selecting which modelling procedure is most appropriate firstly it is noted that the OLS approach, as discussed above, is not well suited to count data and as discussed in Moran et al (2006), can lead to problems during estimation and in particular the validity of the results. Moran et al (2006) also discuss the lack of a natural model selection procedure between the poisson and negative binomial models however the dispersion parameter can be used to infer whether there is an advantage in the negative binomial over the standard poisson. The results show that the negative binomial outperforms the poisson regression for commute trips but not for leisure trips. This is further reinforced by the dispersion parameter which implies that a simple poisson regression may be too restrictive. Therefore it is concluded that the negative binomial is the preferred model and the remainder of discussion focuses on the results of this model.

The cost parameter is estimated as -0.017 for commuting purposes and 0 for leisure purposes. All other parameters within the model are insignificant with the exception of the constant and the dispersion parameter, when the model is re-run with these insignificant variables removed the estimated cost coefficient is statistically indifferent. The insignificance of the non economic drivers is perhaps unsurprising given the characteristics of the sample of respondents which would imply that possibly the majority of respondents have lifestyles in which ‘cash is king’. Taking a more in depth look at the sample respondents, the income levels are disproportionately skewed towards high incomes, working hours are often above 40 and many of the respondents who had reached retirement age continued to work. Although some of this may be a lifestyle choice to remain fit, active and providing oneself with a sense of worth through remaining active within the economy, it is also indicative of a continuing desire to generate an income. The average amount paid for cycles is also indicative that the users of this route are not necessarily representative of the wider areas population. This may also have some implications for the estimated consumer surplus as discussed in the following section.

The insignificance of the income variable was unexpected, though this is perhaps largely due to the sample characteristics, whose incomes are already high and hence the marginal impact is likely to be low as implied by the diminishing marginal returns exhibited in Figure 1.

Valuing the cycle route

In order to place a value on the cycle route, firstly the average consumer surplus must be derived from the results which, following Creel and Loomis (1990) and Moran et al (2006), is done by dividing 1 by the absolute value of the coefficient of travel cost i.e. 1/0.016 for the preferred model. This gives an average consumer surplus of £58.82. These values are comparable to Moran et al (2006) who estimated a recreational cycle trail in Scotland to have an average consumer surplus of £80 i.e. a recreational route has a higher valuation than a route which can be used for more general commute purposes.

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6 a-priori it would be expected that the coefficient for travel cost will be negative thereby ensuring that the estimated consumer surplus is positive. A positive cost coefficient would result in a negative consumer surplus implying that users are paying more than they are willing to.
In order to value the route and not just the journey it is necessary first to pre-multiply the average consumer surplus by the level of demand. This will be done in two ways, firstly using current demand levels as taken from the count surveys and secondly based upon our own knowledge (on-site observation) of the site and its demand levels.

It is assumed that cycling as a leisure pursuit is an all year option, although it is recognised that weather may detract from this, indeed the same may also be true as a means of commuting.

Table 4: Cycle route valuation calculations.

<table>
<thead>
<tr>
<th></th>
<th>Weekday</th>
<th>Weekend</th>
</tr>
</thead>
<tbody>
<tr>
<td>One way 24 hr survey counts (from data provided)</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>One way 24 hr counts (from on-site observation)</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td>Yearly two way 24 hour counts (from data provided)</td>
<td>47*(50*5)=11750</td>
<td>52*(50*5)=14500</td>
</tr>
<tr>
<td>(5 weeks holiday assumed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yearly two way 24 hour counts (from on-site observation)</td>
<td>47*(100*5)=23500</td>
<td>52*(120*5)=31200</td>
</tr>
<tr>
<td>(5 weeks holiday assumed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yearly valuation (from data provided)</td>
<td>(2350<em>58.82)+(2600</em>0)=£552,250</td>
<td></td>
</tr>
<tr>
<td>Yearly valuation (from on-site observation)</td>
<td>(4700<em>58.82)+(5640</em>0)=£1,382,270</td>
<td></td>
</tr>
</tbody>
</table>

5. Conclusions

This paper has provided an empirical study seeking to place an ‘economic’ value on a section of the national cycle route in the region of Edinburgh. Its core contribution being that this is the first known study seeking to evaluate a section of the national cycle route network using such methods. There are a number of conclusions which can be drawn from this research:

- Cycle routes CAN be valued, and therefore can be appraised in some manner.
- The valuation is based on a sub-sample of the population with quite unique characteristics, and not necessarily representative of the population as a whole. We have not directly reflected this, and hence the valuation would be lower than calculated here. As a crude ‘guestimate’, given the relative wealth of the survey population compared to the national average, we would anticipate a per-trip consumer surplus closer to the region of £40.

- The insignificant cost coefficient for the leisure trip model implies a perfectly elastic demand curve. This may further imply the following (i) that the characteristics of the site in question do not impose any surplus utility onto individuals over and above those which they would expect. (ii) Perhaps more realistically that the survey design mechanism used is insufficiently flexible or detailed to represent the characteristics of the leisure users of this site. This is a surprising finding given that the survey template was derived from Moran et al (2006) who effectively applied it for recreational trip purposes.

- The travel costs are disproportionately high due to the income levels of the observed sample, and were demand to increase it would be naïve to assume that this will all come from the same income group, therefore when building future demand scenarios, the income distribution of the existing area should be used to take into account future valuation.
6. Acknowledgements

We would like to offer our thanks to Edinburgh City Council, Fife Council and the Forth Estuary Transport Authority (FETA), who provided us the permission to conduct these surveys and also for the cycle count survey data provided.

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<table>
<thead>
<tr>
<th>Commute trips</th>
<th>Travel cost</th>
<th>Income</th>
<th>Gender</th>
<th>Skill</th>
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<tbody>
<tr>
<td>Age</td>
<td>Education</td>
<td>Constant</td>
<td>Dispersion parameter</td>
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<table>
<thead>
<tr>
<th>Leisure trips</th>
<th>Travel cost</th>
<th>Income</th>
<th>Gender</th>
<th>Skill</th>
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</thead>
<tbody>
<tr>
<td>Age</td>
<td>Education</td>
<td>Constant</td>
<td></td>
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