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Valuing cycling – Evaluating the economic benefits of providing dedicated cycle ways at a strategic network level

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Abstract

In a world where congestion, environmental sustainability and physical inactivity are major concerns, cycling presents itself as a credible way to help address these issues. However, despite the recognition of these benefits, evidence is only beginning to emerge that investments in dedicated cycling infrastructure produce net economic benefits for the community. Historically, difficulties in valuing the benefits of cycling stem from the difficulty in modelling cycling demand and the inability of standard appraisal guidelines to account for cycling-specific benefits such as improved health, whose quantification is pertinent in assessing the viability of cycling projects.

This paper, which considers the economic benefits of the Inner Sydney Regional Cycling Network, is a step forward towards providing a pragmatic, cost-effective method to evaluating the benefits of cycling at a strategic network level. By considering currently available data sources and recent research into cycling route choice, this paper outlines the issues and challenges associated with modelling cycling demand, particularly with respect to modelling the effects of different types of policy interventions, and assessing the associated economic benefits, including health, amenity and environmental benefits.

The application of our approach demonstrates that the provision of high-quality cycling infrastructure can promote cycling uptake and deliver economic returns well in excess of investment and ongoing maintenance.

1. Introduction

As well as providing a means of transport, cycling offers a greater range of benefits for participants and the community (see Sustainable Development Commission 2011, AECOM 2010 and the references therein, Bauman et al. 2008). Although the take up of cycling has increased in recent years (AECOM 2010), the bicycle network in inner Sydney is generally fragmented and disjointed. The lack of quality cycling infrastructure and the perceived dangers associated with mixing with general traffic are key factors identified by potential cyclists as deterrents of cycling within Sydney (Environmetrics 2006).[1]

International and domestic experience (quantitatively) demonstrate that the provision of high quality cycling infrastructure such as dedicated cycleways[2] have a significant influence on ameliorating the safety concerns of potential cyclists (Hopkinson and Wardman 1996; Pucher and Buehler 2008). In Sydney, high increases in demand, albeit off relatively low bases, have been observed on dedicated cycleways such as King Street cycleway and cycleways monitored by the Roads and Traffic Authority (AECOM 2010). Furthermore, Environmetrics'

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[1] Approximately half of all non-regular cyclists within inner Sydney consider general on-road cycling to be sufficiently dangerous to discourage them from cycling. This proportion increases to over 80 percent with respect to on-road cycling within the Sydney CBD (Environmetrics 2006).

[2] Dedicated cycleways are defined here as paths provided for the exclusive use of cyclists whereby cyclists are segregated from general traffic by a physical barrier.

(2006) findings suggest that up to 84 percent of non-regular cyclists would be willing to consider cycling or cycling more often if dedicated cycleways and off-road routes were available.

The development of the Inner Sydney Regional Bicycle Network is a major step towards overcoming the lack of quality cycling infrastructure. The Inner Sydney Regional Bicycle Network will provide a network of 284 kilometres of separated cycleways and shared paths to connect Sydney's fragmented and disjointed cycle network.[3] The objective of this study, undertaken for the City of Sydney Council, is to assess the economic worth of developing the Inner Sydney Regional Bicycle Network, for which AECOM developed:

- a cycling choice model that estimates the effects on cycling demand of providing an extended and improved cycle network with dedicated cycleways
- an economic appraisal framework that considers cycling specific benefits
- an investment tool that assists in the identification of priority corridors for construction and assesses the economic return of fully developing the Inner Sydney Regional Cycle Network.

This paper is organised as follows. Section 2 provides an overview of modelling and appraising cycling initiatives. Section 3 introduces the choice model used in this study, and presents the choice modelling results. Section 4 discusses the cycling economic benefits considered in this study and presents the economic worth of two cycling demand scenarios. Section 5 gives the conclusions for this study.

2. Using economic appraisals to promote cycling

2.1 Background

The role of cycling in promoting better transport, health, social and environmental outcomes is well enunciated. However, the quantification of these benefits is not well established in transport appraisals. This is mainly due to:

- a lack of rigorous methodologies and guidelines available to appraise cycling initiatives
- various difficulties when estimating cycling demand.

Traditional appraisal guidelines usually do not take into account health benefits associated with cycling, the quantification of which is pertinent in driving the viability of cycling projects. Furthermore, as Katz (1996) indicates, traditional transport modelling techniques are not effective in treating a minority mode such as cycling due to the inability of large scale models to account for characteristics unique to cycling.

Guidance on preparing demand forecasting for cycling has been available within an Australian context for some time. Austroads (2001) prepared *Forecasting Demand for Bicycle Facilities* that provides an overview of potential demand forecasting methodologies that vary in difficulty of implementation.

Table 1 presents a summary of key methods used to model cycling demand as well as their data requirements and limitations.

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[3] For an update on the construction progress of the Inner Sydney Regional Bicycle Network visit: http://www.cityofsydney.nsw.gov.au/AboutSydney/ParkingAndTransport/Cycling/CycleNetwork/default.asp.

Table 1: Summary of key methodologies

Methodology	Description
Comparative study and sketch plans	Comparative studies involve making comparisons with other schemes similar to the one being proposed. Sketch plans predict the use of a cycling facility based on rules of thumb about travel behaviour. Arguably, these methods are the least complex to estimate future levels of cycling and the use of these methods in Australia is reasonably widespread (Austroads 2001). However, the difficulty with this method is the many differences that may exist between the study areas being compared such as differences in transport systems and socio-economic characteristics. Also, data used to prepare comparative or sketch plan studies can be considerably difficult to obtain as these sorts of studies are not often published.
Aggregate Behaviour	Statistical methods such as regression analysis can be used to estimate demand across a large area using a range of potential explanatory variables. For instance, Parkin et al. (2008) estimated a logistic regression to investigate the impact of demographics, topology and cycling infrastructure on journey to work cycling mode shares. These methods require statistical knowledge to implement and are generally data intensive. A further drawback is that they become increasingly difficult to apply at a disaggregate level.
Disaggregate choice models	Disaggregate choice models allow for market shares for different transport modes or different routes to be calculated. Choice models calculate the level of utility, or enjoyment, derived by an individual from different combinations of travel time and travel cost for each transport mode. Choice models have the flexibility of including other attributes that may affect transport choice such as socio-economic factors. Disaggregate choice models require considerable technical skill to estimate and apply. Few choice models have sufficient detail to properly assess the impacts of cycling interventions. However, the theoretical background on which these models are based is well recognised and accepted.
Regional travel models	Regional travel models are based on a classical four stage model, that is a four step sequence requiring estimates of trip generation, distribution, mode share and assignment. Although regional travel models are available, the use of regional travel models generally requires resources which are disproportionate to the size of the project. Furthermore, characteristics unique to cycling are typically not well captured by regional travel models (see Sharples 1993) such as: • greater range of travel speeds • ability of bicycles to reach free-flow speeds more quickly than cars • bicycles can move through congested conditions; • sharing of lanes • treatment of illegal manoeuvres.

2.1.1 The role of choice modelling in assessing cycling demand

When current mode shares are known, incremental choice models can be used to forecast the change in market share as a result of changes in utility caused by changes in travel times and travel cost. A key advantage of using incremental mode choice models is that they only require knowledge on current mode shares and future changes in travel attributes to forecast future mode shares. Such an approach is pertinent in assessing cycling investments as the information burden required to forecast cycling demand is reduced significantly.

Whilst the use of choice models to predict transport mode choice is well established, the development of cycling choice models is still nascent. For Sydney, Katz (1996) estimated a multimodal choice model that investigated the effects of variations in cycle path provision, the availability of trip end facilities and bicycle subsidies. Internationally, Wardman et al. (2007) used a choice model to quantify the effects of better on-journey and end-of-trip cycling facilities.[4] The Wardman et al. (2007) model represents a significant advance in attempts to model cycling demand as it is one of the few choice models available that quantify the effects of dedicated cycleways within a multimodal context.

The Wardman model combined Revealed Preference (RP) and Stated Preference (SP) data into a hierarchical logit model. RP data from the National Travel Survey was combined with a specially commissioned RP survey. A number of SP surveys were also undertaken to examine the effects of different types of en-route and trip end cycle facilities and financial measures to encourage cycling. A hierarchical logit model was developed to simultaneously estimate parameters to the two forms of RP mode choice data and the data from the two SP mode choice exercises within a single model whilst allowing for the scale of the parameters to differ between the different data sets. The model was used to forecast trends in urban commuting shares over time and to predict the impacts of different measures to encourage cycling.

The results, shown in Table 2, support the view that cyclists prefer greater segregation from vehicular traffic:

- Dedicated cycleways are considered to be **more than three times more attractive** than cycling without any cycling-specific facilities, to the extent that cycling on dedicated cycleways is considered as desirable as travelling in a car, train or bus.
- On-road cycle lanes to be **twice more attractive** than cycling without any cycling-specific facilities.
- No difference in the desirability of travelling on a major or minor road with no facilities, indicating that the key driver in cycling demand is the extent of segregation between cyclists and general vehicular traffic.

Table 2: Wardman et al. (2007) cycle choice model parameters

Variable	Parameter Value	Relative Attractiveness to Cycling without Any Facilities	Units
In-vehicle travel time – car, train, bus	-0.0390	2.97	minutes
Cycling travel time – separated off-road	-0.0330	3.52	minutes
Cycling travel time – separated on-road	-0.0360	3.22	minutes
Cycling travel time – cycle lanes	-0.0550	2.11	minutes
Cycling travel time – major road with no facilities	-0.1160	1.00	minutes
Cycling travel time – minor road with no facilities	-0.1150	1.01	minutes
Travel cost	-0.0060		pence

Source: Wardman et al. (2007). All parameters were found to be statistically significant at a five percent significance level.
Note: Parameter values are rounded to 4 decimal places.

[4] It is noteworthy that the Wardman et al. (2007) approach has been formally adopted by the UK Department for Transport as part of its Transport Appraisal Guidelines (DfT 2010).

3. Our approach to estimate cycling demand

AECOM adapted the Wardman et al.'s (2007) approach to estimate the effects on current levels of cycling of implementing the Inner Sydney Regional Bicycle Network. The incremental choice model was specifically designed to capture the impact on cycling demand of different cycleway treatments and Wardman et al.'s (2007) model parameters were calibrated to be applied in a Sydney context.

Demand forecasts were estimated for two scenarios:

- **Do-Nothing Scenario:** A base case scenario whereby no changes in cycling infrastructure were assumed. Cycling mode share was assumed to increase modestly over time due to increases in travel times and costs for car, bus and train relative to cycling. Furthermore, aggregate cycling demand was assumed to be influenced by population and employment growth in the study area.
- **Do-Something Scenario:** Represents our estimate of the change in cycling demand expected to be generated from the change in travel costs, travel times as well as from the perceived value attributed by potential cyclists to infrastructure improvements created by the implementation of the Inner Sydney Regional Bicycle Network using an incremental choice model (discussed in Section 3.1).

Key inputs used to model cycling demand are provided in **Appendix B.**

3.1 Do-Something incremental choice modelling

Incremental choice models require an assessment of expected changes in utility. Once the changes in expected utility are known, future cycle mode shares ($p^{forecast}$) can be estimated using the current cycle mode share (p_{cycle}), the expected change in cycling utility (ΔU) and an assumed level of non-trading. The functional form of the model used in this study is as shown in Equation 1**:**

Equation 1: Incremental choice mode share forecast accounting for non-trading for cycling and changes in other modes

$$p_{cycling}^{forecast} = (1 - \text{non-trading rate})\frac{p_{cycling}^{current} e^{\Delta U_{cycling}}}{\sum_j p_j^{current} e^{\Delta U_j}}$$

where j are all other modes considered in the assessment.

A key consideration of cycle demand forecasting is the need to account for individuals who will never consider cycling as an alternative mode (even after the cycling infrastructure improvements have taken place), these are denominated 'non-traders'. Work undertaken by Taverners Research (2007) indicates a non-trading rate in Sydney of 20.8 percent. AECOM adopted this rate in its incremental model.

Using the estimated parameters as shown in Table 2 would have led the choice model to predict larger responses to changes in time and cost than what the Sydney Strategic Travel Model (SSTM) would suggest. AECOM therefore made adjustments to the Wardman et al. (2007) model parameters to enhance their comparability with local travel behaviour in terms of values of time and time and cost elasticities.

Following these adjustments, the scaled Wardman et al. (2007) parameters produced elasticities that closely matched the time and cost elasticities implied by the Sydney Strategic Travel Model.

Unscaled parameter values and rescaled parameter values are shown in Table 3. Implied elasticities using unscaled and scaled parameters with a comparison against the SSTM elasticities are shown in Table 4.

Table 3: Incremental choice model parameters

Variable	Unscaled	Scaled	Units
In-vehicle travel time – car, train, bus	-0.0390	-0.0276	minutes
Cycling travel time – dedicated	-0.0346	-0.0245	minutes
Cycling travel time – cycle lanes	-0.0552	-0.0391	minutes
Cycling travel time – no facilities	-0.1160	-0.0821	minutes
Travel cost	-0.0019	-0.0015	cents

AECOM calculations based on Wardman et al. (2007), Bureau of Transport Statistics (2001), OECD (2009) data. Note: Parameter values are rounded to 4 decimal places

Table 4: Simulated direct time and cost Elasticities

Mode	Unscaled	Scaled	STM
Direct Time Elasticities			
Car	-0.385	-0.273	-0.230
Train	-1.113	-0.787	-0.590
Bus	-0.732	-0.518	-0.600
Cycle	-2.189	-1.549	*No estimates*
Direct Cost Elasticities			
Car	-0.171	-0.137	-0.110
Train	-0.431	-0.345	-0.320
Bus	-0.313	-0.251	-0.350

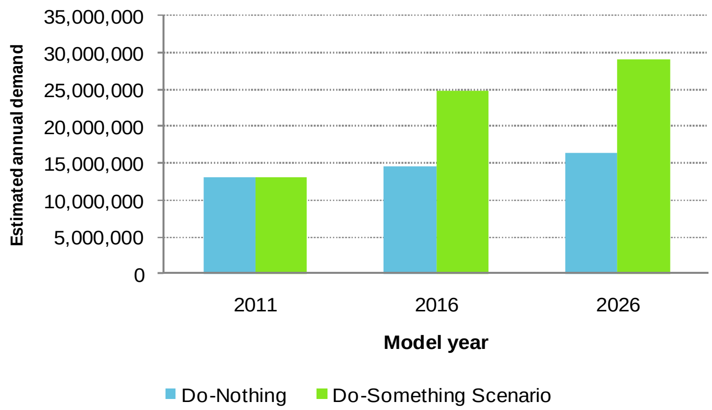
Source: STM elasticities from Bureau of Transport Statistics (2001). All other calculations based on AECOM calculations using Wardman et al. (2007) parameters and average time and cost information from Bureau of Transport Statistics (2001).

A single set of parameter values are presented for dedicated cycleway travel and on-road travel as the differences between dedicated off-road and dedicated on-road facilities were not found to be statistically significant.

3.2 Modelling results

The full development of the Inner Sydney Regional Bicycle Network has the potential to create significant increases in cycling within the study area. *Relative to a do-nothing scenario,* AECOM forecasts that cycling levels will increase by 66 percent by 2016 within the study area and 71 percent by 2026 due to the implementation of the Inner Sydney Regional Bicycle Network, as illustrated in Figure 1.

Figure 1: Forecast annual cycle trip demand by demand Scenario



Source: AECOM calculations.

4. Economic appraisal

4.1 General parameters

Economic benefits of the Strategic Cycle Network were evaluated using standard national and state transport appraisal guidelines. The following parameters were used:

- 30 year evaluation period
- 7% discount rate
- Real indexation of 1% applied on all wage related benefits
- Rule of half applied on all new user benefits such as travel time savings, vehicle operating cost savings, parking cost savings and journey ambiance.

4.2 Economic benefits and costs

Formal guidelines to prepare economic appraisals for cycling interventions are not available currently in an Australian context. However, AECOM understands that a number of government agencies are actively preparing guidelines to facilitate economic evaluations of such interventions. In preparing its economic assessment of the Inner Sydney Regional Bicycle Network, AECOM reviewed all guidance made available and where required, made adjustments and included additional benefit streams. In its economic appraisal, AECOM valued the following benefit streams:

- Decongestion
- Vehicle operating costs savings
- Parking cost savings
- Travel time savings
- Journey ambiance[5]
- Health benefits in the form of reduced mortality and absenteeism savings

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[5] Journey ambiance captures the improved level of enjoyment, improved wayfinding and perceived safety associated with the use of cycle lanes and separated cycleways relative to travelling with mixed traffic.

- Accident costs (that accounts for a dynamic accident rate)
- Reduced air pollution;
- Reduced noise pollution
- Greenhouse gas reduction
- Reduced water pollution
- Reduced urban separation
- Reduced pressure on government infrastructure and services.

In addition to the abovementioned benefits, which were monetised for this study, the Inner Sydney Regional Bicycle Network is expected to generate additional benefits including:

- Improved journey time reliability
- Improved integration with public transport
- Public transport decrowding
- Improved equity and accessibility outcomes
- Potential for wider economic benefits beyond the transport sector
- Improved localised economic activity
- Reduced energy dependence.

Costs considered in the appraisal included:

- Capital expenditure costs
- Maintenance costs
- Accident costs.

For a literature review of cycling specific benefits and detailed information on the formulation of benefits and costs unit rates used in this study please refer to AECOM (2010).

4.3 Appraisal levels

An assessment of the economic benefits generated from the implementation of the Inner Sydney Regional Bicycle Network was undertaken at two levels:

- **A network-wide level:** This meant that changes in aggregate cycling demand and associated economic return due to the *full* development of the Inner Sydney Regional Bicycle Network could be estimated.
- **An origin-destination level:** This meant that changes in cycling demand and associated economic return due to specific cycling infrastructure improvements in the origin-destination route could be evaluated, allowing for the identification of priority corridors for construction.

The economic appraisal was undertaken by appraising the differences in demand between the Do-Nothing Scenario and the Do-Something Scenario.

4.4 Appraisal results

4.4.1 Network level

The full implementation of the Inner Sydney Regional Bicycle Network was predicted to have the potential to generate significant economic benefits in excess of the economic costs and deliver high returns on investment. Relative to doing nothing, the development of the Inner Sydney Regional Bicycle Network was estimated to generate net economic benefits of $507 million in 2010 prices at a benefit cost ratio (BCR) of 3.88.

Table 5: Network wide appraisal results (millions of 2010 dollars)

Criteria	Do-Something Scenario
Present value of benefits	682.3
Present value of investments	153.4
Present value of all costs	175.8
NPV	**506.5**
NPVI	**3.30**
BCR	**3.88**
IRR	**27.1%**

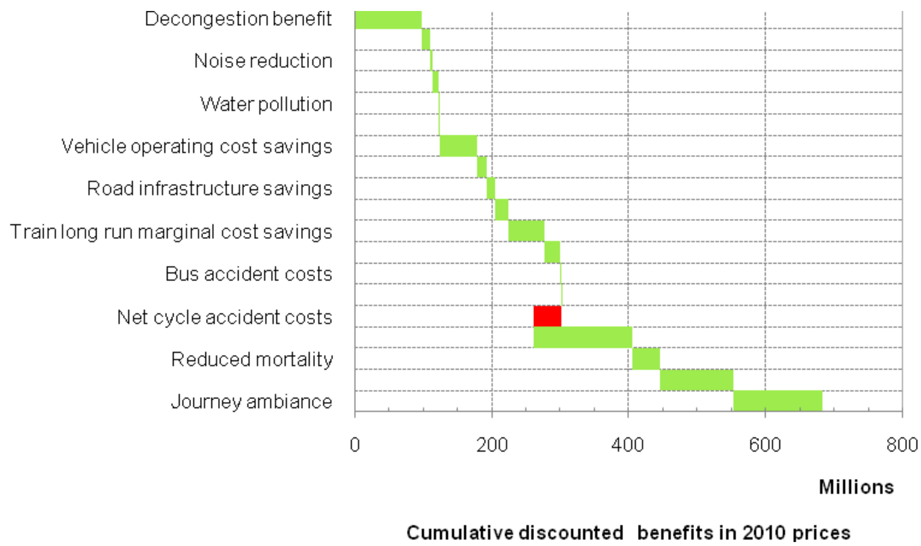
Source: AECOM calculations. All monetary values have been discounted at a real rate of 7 percent per annum over an evaluation period of 30 years and are valued in 2010 prices.

The breakdown of benefits indicated that significant benefits will be accrued by individuals, government and the general economy through the full development of the Inner Sydney Regional Bicycle Network.

Travellers stand to benefit through travel time savings, avoided car costs, journey ambiance and health benefits at the cost of a relatively small increase in accident costs. These benefits collectively accounted for 71 percent of benefits under the Do-Something Scenario. There were also material benefits accruable for government and the broader economy through road and public infrastructure and operating cost savings, environmental benefits and congestion reduction.

The breakdown of the benefits demonstrated the importance of recognising cycling specific benefits. Collectively, health benefits and journey ambiance provided a significant uplift in overall benefits, accounting for 41 percent of total benefits under the Do-Something Scenario. A breakdown of economic benefits under the Do-Something Scenarios is shown in Figure 2.

Figure 2: Breakdown of benefits under Do-Something Scenario



Source: AECOM calculations. All monetary values have been discounted at a real rate of 7 percent per annum over an evaluation period of 30 years and are valued in 2010 prices.

As the figure above illustrates, key benefit drivers were decongestion (97.8 million), travel time (143.6 million) and user cost savings (67.4 million) as well as health benefits (147.3 million) and journey ambiance (129.8 million).

Sensitivity analysis was undertaken on the results, testing the sensitivity of economic benefits with respect to higher capital costs, higher construction costs and lower usage. All sensitivity tests showed that the economic viability of developing the Strategic Bicycle Network was invariant to sensible variations in construction costs, discount rates or usage. The Inner Sydney Regional Bicycle Network was still economically viable even if a “traditional” approach (i.e. removing health and journey ambiance benefits) was used. Indeed, the economic benefits of the Strategic Bicycle Network may well be higher if more aggressive assumptions on the level of health benefits and journey ambiance were applied.

4.4.2 Origin-destination level

Results for the City of Sydney

When demand for trips within the City of Sydney Council area was only considered, the economic desirability of completing the sections of the Inner Sydney Regional Bicycle Network within the council area was high. The net present value of developing the network within the council area was estimated to be $38 million under the Do-Something Scenario with a benefit cost ratio of 3.34.

The City of Sydney’s share of economic benefits from the full implementation of the Inner Sydney Regional Bicycle Network is shown in Table 6.

Table 6: Incremental cost-benefit analysis for the City of Sydney (millions of 2010 dollars)

Variable	Do-Something Scenario
Present value of benefits	54.1
Present value of costs	16.2
NPV	**37.9**
BCR	**3.34**

Source: AECOM calculations. Costs and benefits have been evaluated over a 30 year evaluation period and discounted at a real discount rate of 7 percent. Excludes benefits from public bicycle demand.

Results for other trips

In a network context, undertaking an incremental cost benefit analysis for each individual link is complex. Incremental cost benefit analysis is complicated by the common use of certain links on the network that are difficult to disaggregate. To simplify the analysis, the following steps were undertaken:

- The incremental cost benefit analysis included inter Local Government Area (LGA) trips
- The benefits accrued by the generation of additional intra-SLA trips were not included
- No costs were assigned for origin-destination pairs that had no demand
- Costs for a given origin-destination pair were based on the proportion of the network used
- A network wide sharing factor was applied to constrain the sum of costs to the network wide cost.

Under constrained funding conditions, the benefit-cost ratio is the preferred means of rationing capital. Of 231 possible origin-destination pairs, rankings for 65 pairs by BCR were estimated, where there was a non-zero level of demand.

The incremental cost benefit analysis supported the development of the Bicycle Network within the City of Sydney as well as placing a high priority on radial links from the Inner West and the Eastern Suburbs feeding into the city. On the other hand, the incremental cost-benefit analysis indicated that the economic case for developing corridors from the North Shore into Sydney CBD are highly constrained by the high construction costs associated with developing HarbourLink, a grade separated cycleway between the Sydney Harbour Bridge and Neutral Bay, and cycleways along the Warringah Freeway despite the potential for higher levels of cycling demand.

The top-ten benefit cost ratios under the Do-Something Scenario are shown in Table 7.

Table 7: Top 10 Origin-Destination BCRs

BCR Ranking	Origin LGA	Destination LGA	BCR	Cumulative Cost
1	Randwick	Sydney	54.14	2,242,000
2	Marrickville	Sydney	21.29	3,581,000
3	Botany	Randwick	13.99	4,477,000
4	Leichhardt	Sydney	13.24	5,601,000
5	Waverley	Sydney	11.92	8,015,000
6	Rockdale	Sydney	9.20	10,187,000
7	Canterbury	Sydney	5.23	12,410,000

8	Woollahra	Sydney	5.18	13,700,000
9	Botany	Rockdale	5.14	14,501,000
10	Botany	Sydney	5.01	16,365,000

5. Conclusions

The objective of this study, undertaken for the City of Sydney, was to assess the economic desirability of investing in the development of the Inner Sydney Regional Bicycle Network. For Australia, this study is the first known attempt to estimate the impact of improvements to cycling infrastructure on cycling demand at a (Sydney) network level. The key feature of our demand modelling approach is its ability to model the effects of different types of cycle infrastructure and variations in separation offered by different cycling treatments. Furthermore, our approach relies on publicly available data, accounts for other modes, and could be carried out in standard modelling packages such as Excel. Other attractive features include the consideration of seasonality effects on cycling demand.

On the investment side, our demand modelling and economic appraisal approach allows assessing the economic return of fully implementing the Inner Sydney Bicycle Network as well as of developing strategic cycling corridors. The economic appraisal framework developed for this study considered cycling specific benefits such as improved journey ambiance and health. Results show that the economic return of improving cycling infrastructure in Sydney is high and particularly attractive when considered in a multimodal context.

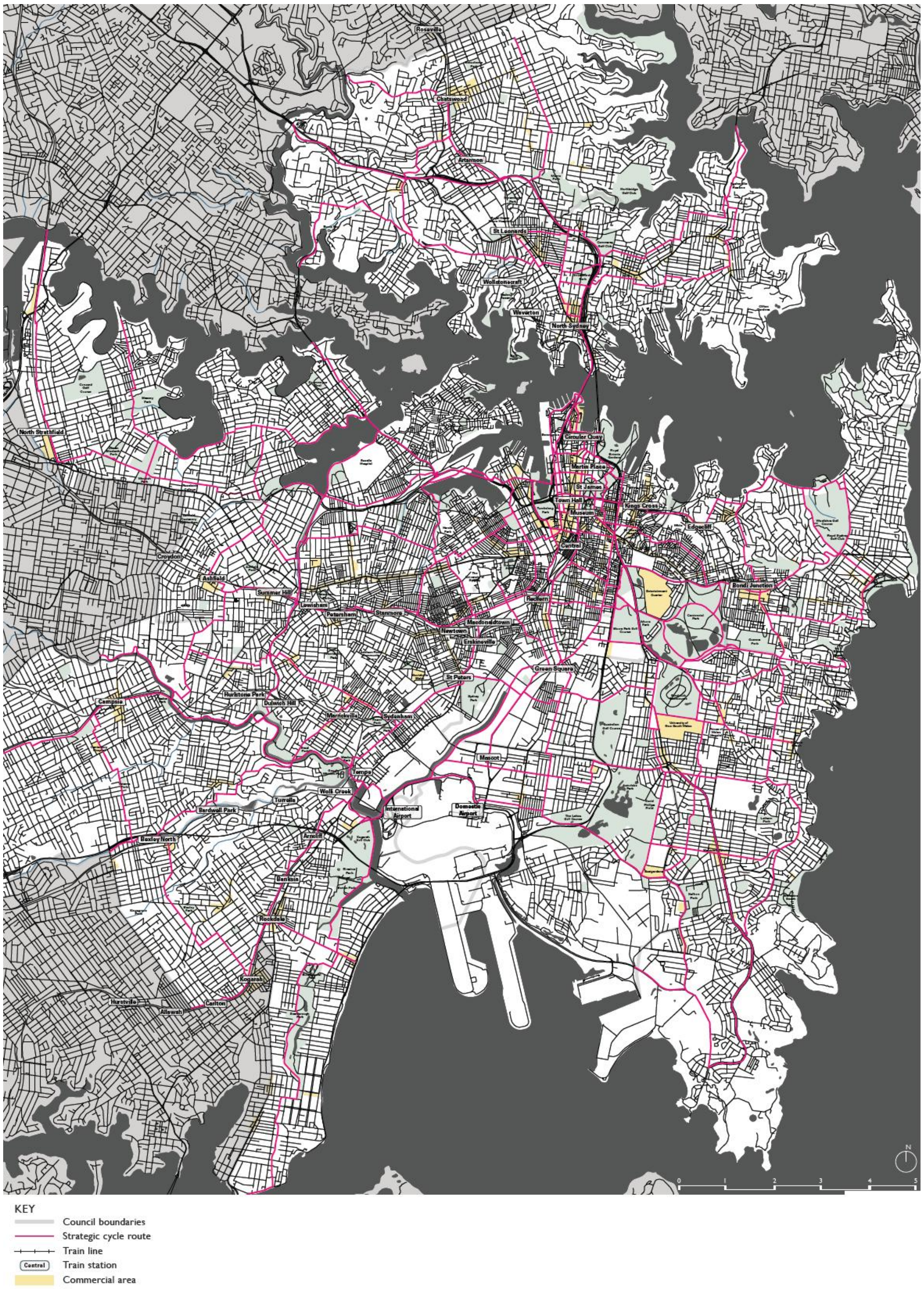
The incremental modelling undertaken for this study suggest that by accounting for the improved protection that dedicated cycleways offer, the full development of the Inner Sydney Regional Bicycle Network has the potential to create significant increases in cycling demand within the study area. Relative to a Do-Nothing case, the incremental choice model predicts that overall cycling levels will increase by 66 percent by 2016 and 71 percent by 2026 due to the implementation of the Inner Sydney Regional Bicycle Network.

The economic appraisal indicates that the full development of the Inner Sydney Regional Bicycle Network is economically desirable. The net economic benefits accruing from the development of the Inner Sydney Regional Bicycle Network, over a 30 year evaluation period and discounted at a real rate of 7 percent, is over half a billion, returning a benefit of around $4 to the community for every $1 invested. The breakdown of the benefits demonstrates the importance of recognising cycling specific benefits. Collectively, health benefits and journey ambiance provide a significant uplift in overall benefits, accounting for 41 percent of total benefits under the Do-Something Scenario. However, the Inner Sydney Regional Bicycle Network is still estimated to produce a net benefit even when removing journey ambiance and health benefits.

Appendix A: Proposed improvements and study area

Appendix Figure 1 shows the routing of the proposed improvements to the bicycle network and the key destinations to be served.

Appendix Figure 1: Proposed Inner Sydney Regional Bicycle Network (routes shown in pink)



Source: AECOM (2009).

The area chosen for this study focuses on current and estimated future demand for cycling within areas proposed to be serviced by the Inner Sydney Regional Bicycle Network. A number of other council areas that will not be covered by the Strategic Bicycle Network but will contribute to demand on the network have also been included as part of the study area. A map of the study area is shown in Appendix Figure 2.

Appendix Figure 2: Study Area

Source: AECOM

Historical cycling activity has been analysed across 26 statistical local areas (SLAs), most of which are within the following statistical sub-divisions:

- Inner Sydney SSD;
- Inner Western Sydney SSD;
- Eastern Suburbs SSD; and
- Lower Northern Sydney SSD.

A list of SLAs considered in this study is shown in Appendix A of AECOM (2010).

Appendix B: Demand modelling inputs

This section outlines key inputs used in this study to model cycling demand.

Base year demand matrices

For the purpose of removing any volatility in the demand as mentioned above, only the car (passenger and driver), train, bus and cycle trips were used from the 2006 Journey to Work matrix.

Current international practice focuses on the use of commuter cycle trips as a basis for estimating aggregate demand and the distribution of demand for all trip purposes as commuter cycling trips are the most predictable. In addition, the reliability of estimating cycling demand using Journey to Work data at a disaggregated level is significantly higher than from other sources. Pivoting off commuter cycling demand was further justified by the greater levels of commuter cycling demand within the study area compared to other parts of Sydney. The use of Journey to Work data as the basis for cycling demand is useful in that it is readily available to most practitioners.

With current cycling demand in Sydney at relatively low levels, excessive disaggregation was not desirable since demand becomes increasingly sparse and unreliable. To enhance the reliability of the analysis, AECOM aggregated demand to focus on inter-Statistical Local Area (SLA) travel, taking a broader perspective of demand along key corridors and between key destinations, an appropriate treatment given the strategic nature of the study.

Considering other trip purposes

Commuting trips, particularly for cycling, only accounted for a proportion of total cycling trips. Hence, factors to expand commuting demand to aggregate demand were required. The 2006 Household Travel Survey data for the study area was analysed to derive factors to convert weekday commuter cycle demand to weekday cycle demand for all trip purposes.

Two factors were used in the demand model:

- A factor of 6.3 to convert intra-SLA commuter cycle demand to all purposes
- A factor of 2.1 to convert longer distance inter-SLA commuter cycle demand to all purposes

The last factor is quite notable in that for longer distance cycling trips, commuting accounts for close to half of all cycling trips (47 percent of trips) whereas for shorter distance trips, commuting is less significant (16 percent of trips). This suggests that different strategies are required to cater for commuting trips, whereby a more strategic approach to planning and infrastructure provision is justified.

Seasonality factor

Some adjustment of base year demand was required to account for the fact that cycling demand is highly seasonal and fluctuates with prevailing weather patterns. Typically, demand for cycling in Sydney reaches a nadir during winter and peaks during spring and autumn. Analysis undertaken by AECOM suggested that the impact of seasonality on cycling demand varies considerably by region, with greater variations in seasonality in colder localities. Left untreated, demand estimates and economic outcomes may be unduly conservative.

In the context that the Census, on which the Journey to Work data is based, is undertaken during early August, daily cycling demand estimates based on unadjusted Journey to Work data is likely to underestimate average daily demand. Data was seasonally adjusted to ensure that Journey to Work demand by cycle reflected annual average levels of demand.

Future year growth in trips

The 2006 Journey to Work Trip matrices were changed over time for 2011, 2016 and 2026 in line with implied population and employment growth forecasts published by the Bureau of Transport Statistics. Accounting for changes in population and employment is important as changes in demand for cycling should occur from changes in aggregate population and employment growth irrespective of the addition of new cycling infrastructure.

Distance matrices

Distance matrices for car, train, bus and cycle were prepared for each of the model years as a basis for predicting travel times and costs as well as computing changes in car, train, bus and cycling kilometres. Distance matrices for car, train and bus were computed using GIS.

Three cycling distance matrices were prepared for each model year, with distances disaggregated by the quality of the facility to be used. CUBE was used to identify the optimal cycle route between SLAs in the study area. By overlaying the Inner Sydney Regional Bicycle Network on top of the general road network, the route choice element within CUBE allowed for the possibility of optimal routes, that may be longer in distance, to be chosen over routes that were shorter if the quality of cycling infrastructure along the optimal route was sufficiently high to outweigh the extra travel time.

To inform the CUBE route choice module, weights of 0.30 and 0.48 were applied to all dedicated cycleways and on-road cycle lanes respectively to account for the higher amenity offered by greater segregation offered by these facilities relative to a road with no facilities. These weights are in line with the Wardman et al. (2007) parameters.

Time and Cost Matrices

Time and costs were estimated using a series of functions, with distance as the key variable. Further information on the development of these matrices is provided within AECOM (2010).

References

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