BIKE-OLOGY:

EVALUATING INTER-URBAN AND RURAL CYCLING INFRASTRUCTURE

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A dissertation submitted to University of Dublin in the partial fulfilment of the requirements for the degree Doctor of Philosophy.

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Declaration

I declare that this thesis has not been submitted as an exercise for a degree at this or any other university. I further declare that except, where reference is given, it is entirely my own work.

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September 2013

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Gerard Kieran Deenihan

Abstract

This thesis reports the outcomes of a study conducted to ascertain the benefits derived from different cycling infrastructure, in rural and inter-urban locations, for different trip purposes. This study came about after an initial study conducted into cycling infrastructure determined that the existing methodologies for analysing cycling infrastructure were very restrictive. There was very little information that related to cycling in rural and interurban contexts. The literature pertaining to recreational and tourist cycling was also limited. There was no clear method for evaluating cycling infrastructure, and what methods did exist, were quite ambiguous.

This study focuses upon the areas of individuals' preferences in relation to the use of different standards of cycling infrastructure for different purposes. The first area examined in this study was a case study of a greenway project in rural Ireland which identified where particular attention for research was required. A stated preference survey was then conducted amongst two target populations; tourists and recreation/commuter users. By conducting this analysis between the different cycling infrastructure types and the different trip purposes, this research provides a detailed account of the values derived from varying standards of cycling facilities.

The stated preference analysis also involved the calculation of the willingness to pay of individuals for cycling infrastructure for recreational, commute and tourist cycling. Health economic analysis was also performed on a proposed cycle route project in a study area. This resulted in the health benefits of the proposed cycle route to be financially estimated, and these type of benefits to be better understood.

From the stated preference analysis conducted in this research, it was determined that different cyclists travelling for different purposes are willing to increase their travel time to cycle upon better cycling infrastructure. It was found that the willingness to pay of the different categories of users for improved cycling infrastructure varied from €0.09 to €0.36 per minute.

The health economic analysis deduced that if a proposed cycle route was constructed, the health economic benefits accumulated over 10 years would be between €26 million and €141 million dependent on the modal shift. The modal shares investigated would reduce the number of deaths per year by between 3.39 and 17.93, depending on the modal shift (2.5%, 5% and 10%). These benefits would result from an initial investment of €12 million. The health economic analysis indicated that the benefit to cost ratios from improved health of the population were between 2.22:1 and 11.77:1, dependent upon the modal switch.

The analysis of the case study, stated preference survey, and the health economic assessment were combined to form a coherent approach for the appraisal of cycling infrastructure. This was used to examine the viability of a proposed cycle route. It was determined that for various usage levels tested that the segregated facility produces better benefit cost ratios than a cycle lane, and therefore greater returns for an investment. It can be calculated for a usage level of 250,000 per annum, the benefit to cost ratio for the segregated facility is 3.6:1, and for the cycle lane, it is 3.5:1. Therefore, the segregated cycling facility represents a much better proposition than the on-road cycle lane.

This analysis also produced new cyclist values of time that vary depending on trip purpose and cycle infrastructure. The values range from €10.98 for a tourist cycling upon a road without cycling infrastructure to €35.19 for a recreational cyclist cycling upon a segregated cycling facility.

Published Research

Journal Papers

Deenihan, G., Caulfield, B., and O'Dwyer, D. (2013) Measuring the success of the Great Western Greenway in Ireland. Tourism Management Perspectives, July 2013, Volume 7, 73-82.

Deenihan, G., Caulfield, B. (2014) Estimating the Health Benefits of Cycling. (Under Review for TRB).

Deenihan, G., Caulfield, B. (2014) The value tourists place on Different Standards of Cycling Infrastructure for Recreational Cycling. (Under Review for Transport Policy).

Conference Papers

Deenihan, G., Caulfield, B., O'Dwyer, D. (2012) Analysing the Usage of a Segregated Interurban Cycleway (Greenway) in Ireland. Presented at the 91st Transport Research Board, January 2012, Washington D.C.

Deenihan, G., Caulfield, B. (2013) Determining the "Willingness to Pay" of Tourists, Commuters and Leisure Users for Different Types of Cycling Facilities. Presented at the 1st Bicycle Urbanism Symposium, June 2013, Seattle, Washington.

Deenihan, G., Caulfield, B., O'Dwyer, D. (2012) Analysing the Usage of a Segregated Interurban Cycleway (Greenway) in Ireland. Presented at the 3rd Irish Transport Research Board, August 2012, University of Jordanstown, Belfast.

Deenihan, G., Caulfield, B. (2013) Determining the "Willingness to Pay" of Tourists, Commuters and Leisure Users for Different Types of Cycling Facilities. Presented at the 4th Irish Transport Research Board, August 2012, Trinity College, Dublin.

Deenihan, G., Caulfield, B. (2011) Route selection of the proposed cycle route along the Dublin to Mullingar Corridor. Presented at the 2nd Irish Transport Research Board, August 2011, University College, Cork.

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List of Abbreviations

AICc	Akaike Information Criterion Coefficient
CBA	Cost Benefit Analysis
GIS	Geographic Information Systems
GPS	Global Positioning System
HEAT	Health Economic Assessment Tool
IIA	Independent of Irrelevant Alternatives
MNL	Multinomial Logit
OECD	Organisations for Economic Cooperation and Development
TCD	Trinity College Dublin
USA	United States of America
UK	United Kingdom
WHO	World Health Organisation

1 Introduction

“The bicycle is the greatest Invention of all time” (BBC Radio 4, 2005). In 2005, BBC Radio 4 conducted a survey amongst thousands of people living in Britain, in order to identify the greatest invention of all time. 4,500 people responded to the survey and 59% of the respondents voted that the bicycle was the greatest invention of all time (BBC, 2005). Therefore, it is quite evident that this invention is very popular, however, when the travel modes of individuals are observed, this mode of transport usually features in the lower end in the spectrum of travel modes. This is an unfortunate occurrence, as the benefits of cycling are widely documented (increased health of individuals, good for the environment, efficient use of space in cities, etc) (WHO, 2011). This feature of cycling appearing so low in travel mode percentages, yet retaining its popularity as an invention first came about in the post World War II Era. This coincided with the beginning of large scale production of the automobile. Up until the 1950s, cycling was seen as a classless mode of transport, where both labourers and the aristocracy could both utilise this mode. Following the 1940s, the automobile then became the de rigueur choice for the middle and upper classes, and therefore the more desirable mode of transport (Buehler and Handy, 2008). In most countries cycling saw startling declines in travel mode percentages between the 1950s and 1980s (Buehler and Handy, 2008). During this time, a few select countries and cities did introduce policies in favour of cycling, and so some notable percentage was retained for cycling as a travel mode.

It was only in the 1970s that this phenomenon received some academic attention, and it was not until the late 1990s and early 2000s that issues pertaining to cycling started to be researched more widely (Pucher and Buehler, 2012). In Ireland at a government level, it was not until 2009 that Ireland’s first National Cycling Policy Framework was adopted (Smarter Travel Office, 2009). The primary aim of this document was to promote a cycling culture within Ireland, and it contains many specific objectives to be achieved by 2020. One of the aims was to conduct a scoping study to investigate the development of a national cycling network. In 2010, the National Roads Authority published the National Cycle Network Scoping Survey (National Roads Authority, 2010). This scoping survey identified 2,000km of cycle corridors to be developed across Ireland. These corridors were selected to maximise the development of cycling as a means of transport for commuting, whilst also encouraging the development of leisure and tourist cycling, by linking many urban areas. They are also aligned with tourist and economic development in mind. This national cycle network serves many regions of the country and covers most of the major gateways into the country, allowing tourists to access the rest of the country easily. From this larger network, smaller networks can be developed by local authorities and Fáilte Ireland. The report stipulated that this network will form the basis for funding long distance cycle route projects in Ireland, and therefore, ensures that cycling investment is aligned with long term national plans. A map indicating the routes that these cycle corridors pass along can be seen in Figure 1-1, where the 2,000km of cycle corridors can be seen.

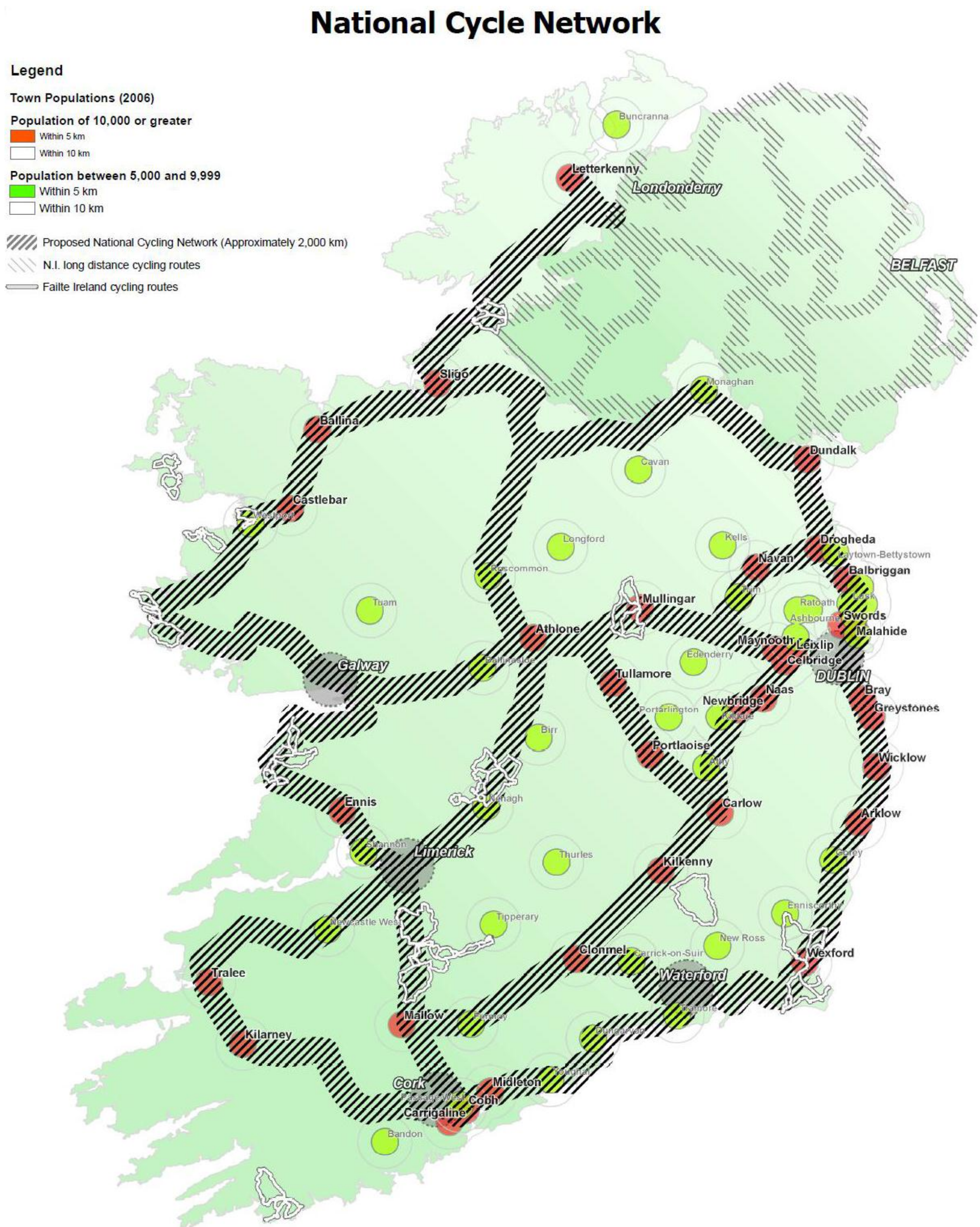

Figure 1-1 National Cycle Network

(Source: National Roads Authority, 2010)

1.1 Project Overview

When constructing the national cycle network, the Dublin to Galway corridor was selected as the first corridor for further route feasibility and delivery. This corridor passes through large tracts of suburban Dublin, numerous settlements such as Mullingar and Athlone, and serves many other urban settlements, as seen in Figure 1-1. There were many reasons for this corridor being progressed as the first corridor, such as:

- The route commences/terminates in two of Ireland's largest tourist destinations (Dublin and Galway).
- There are several other tourist destinations along the route.
- This corridor serves many key urban centres and the population density is relatively high.
- There are various means of accessing public transport along the corridor.
- There is a wide range of existing infrastructure that could be utilised such as canal towpaths, disused railway lines, and hard shoulders of previously designated national roads.
- The cycle route planned is also part of Eurovelo Route 2 extending East-West across Europe, connecting Galway to Moscow and many cities in between (EuroVelo, 2013).

Within this corridor, the section between Dublin and Mullingar was selected as the first phase of the overall route between Dublin and Galway, to be developed. It was chosen as the first phase because it contains densely populated residential centres, large employment centres, and several tourist attractions. The population of this corridor was 141,777 in 2011 (Central Statistics Office, 2012). The proposed cycle route also serves a number of companies. There are over 5,000 people employed in the Intel Ireland complex, and over 4,500 people employed by Hewlett Packard Ireland, in Leixlip. There are over 8,500 students in attendance at the National University of Ireland, Maynooth, and over 9,200 primary school students and 6,300 post primary school students in education, along the corridor.

In the spring of 2011, a route feasibility study was conducted by Trinity College, Dublin (TCD) for the National Roads Authority. Please see Appendix 1 for a copy of the synthesis report of the scoping study carried out by TCD. In this study three different routes along which the cycle route could be constructed were examined. These routes were:

1. On-road cycle lane along the R148.
2. Off road cycling facility segregated from traffic along the Royal Canal towpath.
3. Hybrid option of both on-road cycle lane and off road segregated cycling facility.

The various routes that were investigated as part of this study can be viewed in Figure 1-2. The route along the Royal Canal Towpath is indicated in blue, the route along the road is indicated in red, with potential variations indicated in orange. It can be observed that all the routes under consideration effectively serve the same areas. These routes differ mainly in respect to the type and perceived quality of the cycling infrastructure.

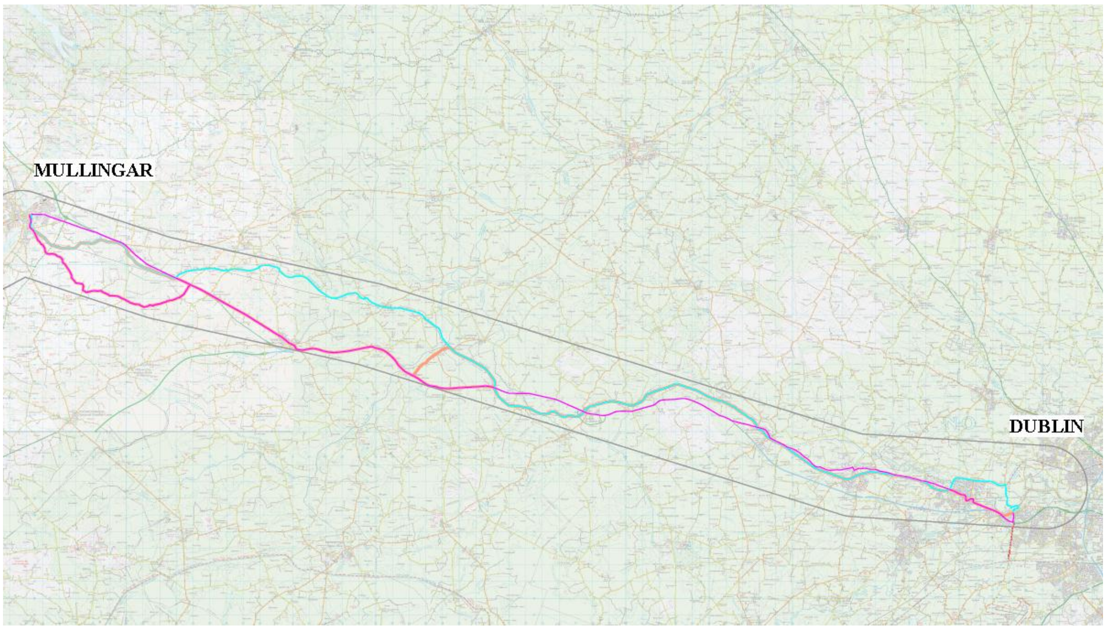

Figure 1-2 Potential Routes in Dublin to Mullingar Corridor

It was determined in this feasibility study that the preferred route from Lucan to Mullingar would pass along the Royal Canal. This route was identified as the preferred route after an extensive inspection of the existing infrastructure in the area, where it was identified that the on-road cycle lane would cost approximately the same, as the off road segregated cycle lane using the Royal Canal towpath. An overview of the settlements that this preferred route passes can be observed in Figure 1-3. It can be seen that this route passes through several key urban centres whilst also being segregated from traffic, increasing the perception of safety of potential users, whilst also maximising potential local usage.

Figure 1-3 Map of Royal Canal Route Option

A map outlining the study area can be seen in Figure 1-4. The preferred route of the cycle route identified in the scoping study is displayed in blue. It can be observed how the route passes through the urban centres of Mullingar, Enfield, Kilcock, Maynooth, Leixlip and Lucan. A buffer zone of 5km was placed around the preferred route. The edges of this zone are displayed in red. This zone encompasses most of the major settlements in the area. The population densities of each electoral district in the area can also be seen. Each green dot represents two people. As expected, the population density increases with proximity to Dublin City. It can be observed how there are many settlements along the preferred route that have high densities relative to the surrounding countryside. The road infrastructure is shown in yellow on the map.

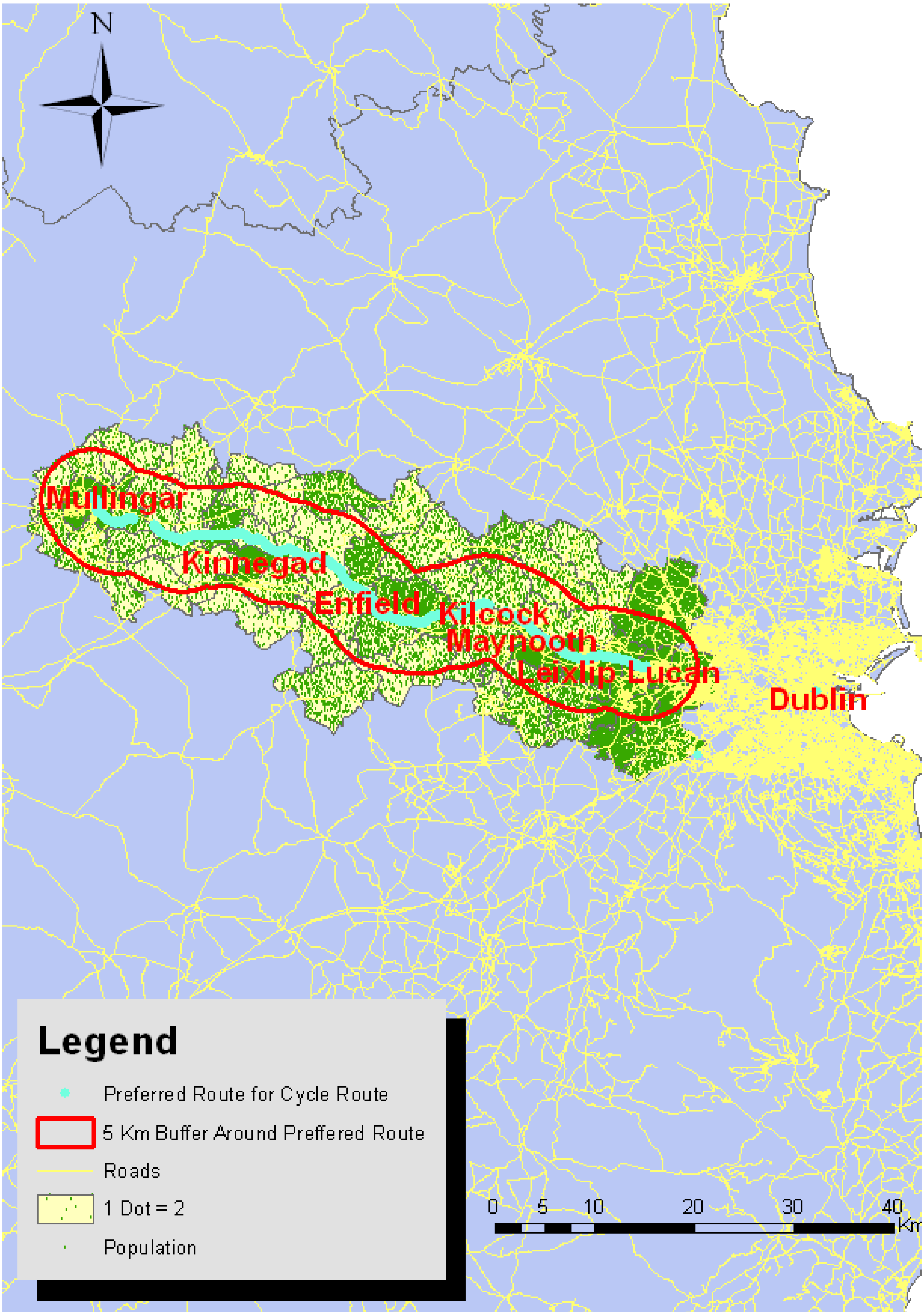

Figure 1-4 Lucan to Mullingar Corridor

While conducting the route selection report, it became apparent that there was no structured methodology for determining the preferred route. In most transport infrastructure cases, the measure of the potential success for a proposed transport project is decided by time savings. For cycling infrastructure, this is not the most effective way of selecting cycle infrastructure, since there are a number of other factors that are necessary to consider, such as improved safety and health, and the aesthetics along the route. There was also a lack of information relating to usage by non commuters, with usage by recreational users and tourists excluded from most appraisal methods. What little research that has been completed in cycling appraisal has mainly been set in the urban context. Due to the paucity of research in these areas, it was decided that these matter should be investigated further.

1.2 Research Questions

There was a distinct lack of clarity for an approach in the evaluation of cycling infrastructure when the route selection report was being completed. There were many evaluation methods that could be utilised; however, each method had disadvantages as some substantial aspects in the evaluation were ignored (namely health, safety, comfort, etc). The results of these methods are often ambiguous. There was also very little attention directed towards cycling for non-commute purposes, specifically recreational and tourist cycling. The little research that exists in these areas is mainly focused on the urban context, with rural and interurban cycling receiving very little consideration.

From the issues raised in the route feasibility study conducted by TCD it was decided to conduct further research into a few select areas. It was determined that the objectives of this research would be as follows:

1. To conduct a detailed literature review in the following areas: i) Cycling in Ireland, ii) Greenways – International and local experience, iii) Methods of evaluating cycling infrastructure, iv) Health and economic benefits of cycling, v) Cycling for tourist and recreational purposes.
2. To conduct a case study of a similar cycle route project in Ireland and to examine how this effects commuting, recreational and tourist usage.

3. To develop a stated preference survey using a fractional factorial design to measure respondent's preferences and attitudes to varying standards of cycling infrastructure.
4. To investigate and model the choices made by respondents in relation to the differing standards of cycling infrastructure, using a multinomial logit approach.
5. To examine the impacts of explanatory variables, such as socio-economic characteristics on the utility, derived from different cycling infrastructure.
6. Estimate the willingness to pay amounts for people for different trip purposes, for differing standards of cycling infrastructure.
7. Develop cyclist values of time for differing trip purposes and differing cycle infrastructure types.

1.3 Structure of Thesis

The remainder of this thesis is structured as follows: firstly it was necessary to examine existing literature on the benefits of providing cycling infrastructure, and how this infrastructure is evaluated. **Chapter 2 Literature Review** considers the literature in various areas relevant to cycling. This chapter provides a background to the research previously carried out pertaining to cycling, and other countries around the world. It is in this chapter that the gaps in the existing literature are more readily identified and explained.

Chapter 3 Case Study and Scoping Survey: describes two preliminary studies that were carried out at the start of this research. A case study undertaken in Ireland is discussed, followed by the scoping survey identifying the attributes affecting cyclist behaviour. The methods underpinning the case study and the attribute analysis are discussed.

Chapter 4 Methodology: outlines the theories that underline the stated preference analysis undertaken in this thesis, and the process under which the analysis was performed. The health economic analysis is also discussed in this chapter. This chapter assesses the approaches used to collect and analyse the data.

Chapter 5 Summary of Survey Statistics: presents the results of the survey undertaken amongst the tourists, and the population of the study area. This chapter is divided into two sections where the responses to the questions posed in two surveys are detailed.

Chapter 6 Stated Preference Analysis: presents the analysis performed on the stated preference surveys conducted amongst the tourists and the study area population. In this chapter, a series of explanatory variables are incorporated into multinomial logit models, to ascertain the impact these variables have on the results. These models are used to calculate the willingness to pay values for the tourists and the study area population.

Chapter 7 Health Economic Analysis: conducts an investigation into the health benefits in the study area, from the construction of the cycle route. In this chapter, different usage levels are theorised for the proposed cycle route, and the health economic impacts of these usage levels are calculated and presented

Chapter 8 Overall Benefits: combines the research conducted in the previous chapters into one coherent method for evaluating cycling infrastructure.

Chapter 9 Conclusions: outlines the conclusions from the analysis along with the impact of this research. This is complimented by a critical assessment, followed by the identification of areas where future research could be conducted.

2 Literature Review and Background

2.1 Introduction

This chapter introduces the research that has been undertaken into cycling, and the methods that are used to analyse cycling. The concepts behind this research and the purposes and benefits of this research are outlined. The first section of this chapter describes the research and the relevant government policies that exist in Ireland, to set the scene for the current state of cycling in Ireland. Research that presently exists into greenways is then outlined. This is followed by a description of the methods that currently exist for evaluating and analysing the benefits of constructing cycling infrastructure. The theory of stated preference surveys and the reason for using this particular method in this thesis is stated. Following on from this, the health and economic benefits that accrue from cycling are discussed. The subsequent two sections discuss cycling relating to tourism and recreation respectively. This chapter concludes with a summary of all the sections outlined within this chapter, and identifies the current gap in the research, which this study seeks to fill.

2.2 Cycling in Ireland

Presently, cycling as a modal share of commuting to and from work and education in Ireland is increasing after several years of decreases being recorded. Table 2-1 displays how cycling as a means of transport to and from places of work decreased between the years of 1996 and 2006, but increased between 2006 and 2011, within four out of the five cities in Ireland (Central Statistics Office, 2012). It can be seen in Table 2-1 that Dublin recorded a substantial increase in cycling between the years of 2006 and 2011.

Table 2-1 Population of the Five Largest Cities in Ireland with the Cycling Rates

City	2011 Population	1996 Cycle Rate		2002 Cycle Rate		2006 Cycle Rate		2011 Cycle Rate	
Dublin	1,270,603	22,922	6%	19,950	4%	20,588	4%	26,670	5%
Cork	518,128	2,520	2%	1,660	1%	2,012	1%	2,617	1%
Galway	250,541	2,152	3%	1,486	2%	2,045	2%	2,423	2%
Limerick	191,306	1,788	3%	1,106	2%	1,174	1%	1,119	1%
Waterford	113,707	1,225	4%	621	2%	601	1%	616	1%

It can be seen in Table 2-1 that cycling has the greatest modal share in Dublin City. This has led on to several studies being carried out in the city. The increases in cycling in Ireland can be attributed to several government policy interventions involving cycling since 2006. These interventions are quite varied and are outlined within this section.

2.2.1 Policy Interventions to Increase Cycling

Since the census was conducted in 2006, there has been a greater emphasis on the provision of cycling infrastructure and policies in Ireland. Some of the most successful schemes are the “Bike to Work” scheme, a greenway construction programme, and the introduction of a bike sharing scheme in Dublin.

“Bike to Work” Scheme

The “Bike to Work” scheme provides tax-free loans for the purchase of new bicycles by those in employment. Over 4,000 employers are registered with this scheme which was launched in January, 2009 (Independent News and Media, 2013). Caulfield and Leahy (2011) investigated the benefits of this “Bike to Work” scheme. This investigation was conducted by means of a survey. The study found that the majority of respondents were aged between 25 to 34, and 35 to 44. The study concluded that the tax-free loans scheme had been successful in attracting a greater percentage of females, and those in older age groups, to cycling on a more regular basis in Dublin.

Construction of Greenways

In August 2010, the Department for Transport launched the National Cycle Network Scoping Study. This document envisages the creation of over 2,000km of greenways and high quality cycle paths throughout Ireland (National Roads Authority, 2010).

One of the first of these Greenways to be launched was the Great Western Greenway in Mayo, in the North West of Ireland. Deenihan et al (2013) investigated the success of the Great Western Greenway. The Greenway was constructed along a disused railway line with the main purpose of attracting tourists to the area. It was found that the project was very successful at attracting many more tourists than initially thought. The Greenway was found to have a payback period of six years. This project also led to increased sustainable travel amongst the local population, with many people using the project to commute to and from their places of work and education, and for recreational purposes. A case study of this project is presented in Section 3.2 of Chapter 3.

Dublin Bike Hire Scheme

The "Dublin Bikes" scheme was launched in September 2009. This is a public bicycle rental scheme that launched with 450 bicycles and 40 stations. This scheme has been judged to be very successful, and is believed to be one of the most successful bicycle sharing schemes in the world. Caulfield (2013) examined the growth in cycling in the Greater Dublin Area between the years of 2006 and 2011. This paper determined that the "Dublin Bikes" scheme was one of the fundamental reasons for the increase in the cycling rate in the city. The results from the analysis showed that the growth in cycling in Dublin, resulted in a greater percentage participating in cycling, especially: females, those belonging to a higher age category, and those from a higher socio-economic class. This paper also identifies increased investment in the cycling infrastructure in Dublin, and the lowering of the speed limits in the city centre, as reasons for the increase in the cycling rate.

2.2.2 Safety

One of the main areas of research into cycling in Ireland has been in the area of safety, and the perceptions of cycling. Lawson et al (2013a) conducted a study of the perceptions of safety for cyclists in Dublin City. This study concluded that cycling was perceived as an unsafe mode of transport. It also provided evidence that young cyclists were more likely to consider cycling as an unsafe mode of transport than older cyclists, and established that when the regularity of cycling increased, the perceived safety of cycling increased.

This study was complimented by Caulfield et al (2012) who looked at infrastructure preferences for cyclists in Dublin. This was completed so by presenting respondents with scenarios, in a stated preference survey. The scenarios within this survey contained attributes of travel time, cycle route type, cycle route traffic, number of junctions, and adjacent vehicular traffic speed. It was found that a shared “cycle lane/bus lane” and a “no lane” options were very unlikely to be chosen by respondents. It was found that the “off road cycle lane” option, followed by a “greenway” option were both very highly valued by respondents. Respondents who walked and cycled to work had the greatest value of time for journeys to and from work, and those that drove or took public transport to and from work had a poor perception of cycling. In 2006, the Greater Dublin Area had a very low cycling rate relative to other European Cities. The cycling rate was comparable to that of many American cities. This study demonstrated that with the right combinations of policies and investment, it is possible to increase the cycling rate and alter the perception of cycling. After reviewing the existing research regarding cycling in Ireland, it was evident that there was a lacking in the examination of cycling with rural areas, and particularly so for the interurban contexts. It can also be observed in this section that commuters have received most of the attention in research, and studies of leisure and tourist cyclists have not been overly developed. This indicated to the author that the area of leisure and tourist cycling, along with rural and interurban cycling required more attention. This area is further discussed in Sections 2.7 and 2.8.

2.3 Research of Greenways

As stated in Section 2.2, the construction and planning of greenways has become an important topic in Ireland. A number of international case studies have been published on the benefits of greenways. Richardson (2006) examined the results of intercept surveys on Switzerland’s National cycle network over a three-year period. The surveys gathered information at sixteen random locations around the network. Temperature, rainfall and cyclist numbers were noted over a period of time at these locations, and for certain times of the year, every year, for three years. Intercept surveys were carried out on a passing cyclist, every time a certain number of cyclists passed. This information allowed for specific types of cycle flows (purpose/leisure/tourist) and weather patterns to be correlated. The intercept surveys allowed the trip types, distances travelled and the contribution to the local economies to be determined. This paper concluded that there are about 7.2 million day trips on the network, and 350,000 overnight trips annually on the network. Other benefits of investing in cycling infrastructure include the improvement in the international and national image of a location.

Downward et al (2009) wanted to determine the economic impact of sports tourism, by looking at the economic impact of a network of Greenways constructed in the North East of England. It was established that for leisure and tourist related cycling, expenditure and duration of trip had the largest affect on trip length. Duration did not directly affect expenditure and different route characteristics for this category of cyclists. Income and, if the users were in a group, group size, were the key determinants in sports tourism expenditure. It was found that when planning infrastructure that targets tourists and leisure users, it is important to ensure that the infrastructure can cater for longer trips.

Manton et al (2014) carried out a life cycle assessment of a greenway in Ireland, in order to determine the carbon costs and savings of this type of infrastructure. It was found that a 10km greenway with a life span of 20 years would require 115 commuters annually, commuting 10km/day, and changing travel mode from automobile to cycling, to cancel out the carbon footprint of constructing the 10km greenway. It was found that the carbon footprint for the greenway could be reduced in the following ways: by using recycled asphalt and demolition waste in the construction process, using locally sourced crushed rock and gravel, and local recycled material in the sub-base and capping layers, and utilising novel materials in the base and sub-base layer knowing the reduced loads imparted by bicycles. Manton and Clifford (2012) examined the factors that influence the route selection of cycle routes and greenways in Ireland. These were identified and classified. Three distinct user groups were identified that cycle routes can cater for. These were cycle tourists, leisure cyclists and commute cyclists. By comprehensively identifying potential user groups, existing infrastructure and affecting factors, it was possible to identify five potential routes in a case study.

In 2009, Cleaveland (2009) carried out an extensive review of investments in Greenways, in several locations throughout the USA, during the 1990's. In Austin, Texas, from 1990 to 2000, the cycling rate for Austin increased from 0.76% to 0.95% of total modal share, and within a bicycle analysis zone where the cycle infrastructure was provided; there was an increase from 2.64% to 3.52% of total modal share. In Chicago, Illinois, the cycle rate increased from 0.28% to 0.50%, and for a bicycle analysis zone; there was an increase from 0.35% to 0.67%. In Colorado Springs, the cycle rate increased from 0.26% to 0.34%, and within a bicycle analysis zone, the increase in the cycling rate went from 0.91% to 0.95%. In Salt Lake City, Utah, however, conversely to the other cities; the cycle rate remained the same after the investments. The cycling rate recorded in the city dropped from 1.52% to 1.49% between 1990 and 2000, and for the bicycle analysis zone, the rate was 1.53% for both years. Madison, Wisconsin, did not experience any change in the cycling rate for the city, between 1990 and 2000. Within the bicycle analysis zone there was an increase from 1.30% to 1.62%. Cleaveland (2009) identified three themes that are important when considering new cycling infrastructure. These were; location of facilities along usable commute routes, overall network connectivity, and the amount of publicity and promotion provided.

Other research pertaining to Greenways in Ireland was completed by Manton and Clifford (2013). This paper continued the research from Manton and Clifford (2012) by reviewing the design and maintenance of greenways in Ireland. This involved investigating the user groups identified in Manton and Clifford (2012) and analysing the specific requirements of each group. It was found that a cycle route for tourist cyclists would need to be safe and continuous, be in a countryside setting, with cyclist friendly cities and towns along the route and have clear and reliable signage along the route. Leisure cyclists were found to be a very diverse group, which includes occasional cyclists, experienced cyclists, and also families and children. The trips can vary in length from short cycles to longer day trips. The design implications for these groups were identified as: width, speed, gradient, alignment, crossfall and materials.

When considering cycling infrastructure such as greenways, it is important that the evaluation of these facilities be fully understood. Section 2.4 details the various methods that can be utilised to evaluate cycling infrastructure.

2.4 Evaluation of Cycling

This section examines international and national research in relation to methods of evaluating the impacts of investing in cycling infrastructure. The evaluation of cycling facilities can be broken into two distinct categories:

1. Evaluation of existing cycle infrastructure.
    - The approaches used for existing infrastructure are: Geographic Information Systems (GIS), statistical analysis, and revealed preference surveys.
2. Evaluation of proposed cycle infrastructure.
    - The approaches used for proposed infrastructure are: cost benefit analysis, multi criteria analysis, and stated preference surveys.

A synopsis of the most relevant studies using these methods is shown in Table 2-2. It can be seen which evaluation methods were used for appraising existing and proposed cycling infrastructure, and the years that these methods were used. Some of these methods of evaluation are relatively recent, whereas other methods have been widely used for years. The use of GIS is the newest methodology for evaluating cycling; therefore the literature is relatively recent. Whereas the use of stated preference survey has been in existence for longer and therefore, the literature is more widely spread over different years. There is an extensive list of literature that utilises these various evaluation methods, however, only the most relevant literature is included in Table 2-2.

Table 2-2 Studies and Evaluation Methods

Evaluation Method	Planned Infrastructure or Existing Infrastructure	Year	Author(s)
Geographic Information Systems	Existing Infrastructure	2010	Menghini
	Planned Infrastructure	2010	Rybarczyk and Wu
	Planned Infrastructure	2009	Cordera
Statistical Analysis	Existing Infrastructure	2009	Burbridge
	Existing Infrastructure	2013	Lawson et al
	Existing Infrastructure	2005	Birk and Geller
Revealed Preference Survey	Existing Infrastructure	2009	Downward et al
	Existing Infrastructure	2009	Akar and Clifton
	Existing Infrastructure	2009	Kemperman and Timmerman
	Existing Infrastructure	2004	Stinson and Bhat
Cost Benefit Analysis	Existing Infrastructure	2004	Sælensminde
	Planned Infrastructure	2009	Department of Finance
	Planned Infrastructure	2011	Browne and Ryan
Multi Criteria Decision Analysis	Planned Infrastructure	2011	Browne and Ryan
	Planned Infrastructure	2009	Cordera
Stated Preference Survey	Planned Infrastructure	2010	Sener et al
	Planned Infrastructure	2003	Stinson and Bhat
	Planned Infrastructure	2007	Tilahun et al
	Planned Infrastructure	2007	Wardman et al
	Planned Infrastructure	1996	Hopkinson
	Planned Infrastructure	2009	Bonsall

2.4.1 Evaluation of Existing Infrastructure

This section outlines the methods that presently exist for analysing existing cycling infrastructure.

Geographic Information Systems (GIS)

GIS is a system where geographical data can be captured, stored, manipulated, and analysed, and allows geographic information to be displayed that can then inform decision making. GIS can help transportation planners analyse and manage overall cycle networks, cycle parking and community bike programs.

Menghini (2010) evaluated the route choice of cyclists in Zurich, by using global positioning system (GPS) data. It was possible to estimate high quality route choice models for cyclists from GPS data. It was important that direct and marked routes for cyclists existed, in conjunction with the avoidance of steep gradients for longer routes. The study concluded that cyclists avoided signal controlled junctions, and that policies that aim to increase the amount and length of cycling should provide direct, indicated paths between the origins and destinations of the travellers.

Rybarczyk and Wu (2010) examined bicycle infrastructure planning by integrating GIS and multi criteria decision analysis (Multi criteria decision analysis is detailed in Section 2.5). This method was applied to Milwaukee City, Wisconsin, USA. The study concluded that combining GIS and multi criteria decision analysis can be used for the design of optimal bicycle facilities; however, inadequacies were highlighted in typical supply-side measures. It was found that safety is a major determinant in a cyclist's choice of routes. Bicycle levels of service are generally better in local and collector roads and worse on major arterials, however, local and collector roads have lower demand potentials, while major arterials have elevated demand potentials.

This method of using geographic information was discounted for this study. The area under investigation does not have a high amount of existing cyclists; therefore obtaining a sufficient amount of GPS data would be very difficult. This study also sought to evaluate the appropriate route for a planned cycle route in the study area. Tracking the existing routes of cyclists would not be appropriate for determining the route of a completely new cycling facility, due to some of the proposed routes not being used by cyclists or having any cycling infrastructure. The use of GIS also requires significant amounts of high quality data, such as average annual daily traffic, average travel speeds, etc. This type of data is not readily available for some of the infrastructure where the proposed cycle route was being considered.

Statistical Analysis

Statistical analysis can be performed on various datasets, and used to evaluate the performance of existing or planned cycling infrastructure. These datasets can be derived from many sources such as household surveys and census results. By analysing census results in conjunction with mapping analysis, it is possible to identify an area with existing cycling infrastructure, and determine the cycling rate, and compare this to the cycling rate from an area with little cycling infrastructure. Burbridge (2009) evaluated the impact of a neighbourhood trail on active travel behaviour, and overall physical activity among suburban residents in Salt Lake City, Utah. It was found that the construction of the trail did not have a significant positive effect on the active travel behaviour levels of the neighbourhood residents, in the short term. The trail segment, although part of a larger network of infrastructure is only 1 mile long.

Other statistical analysis options using census results are analysis with respect to personal demographics and other external factors. Lawson et al (2013b) conducted one such study in Ireland. This study analysed non-motorised commuter journeys in five major cities in Ireland. It was found that increased car ownership, and longer commute distances led to a decline in the numbers participating in active travel modes (walking and cycling), in Ireland between 1991 and 2006. It was established that males were three times more likely to cycle than females. It was found that the smaller cities that were included in the analysis had a smaller uptake in non-motorised travel modes.

Birk and Geller (2005) investigated the increase in cycling in Portland, Oregon over a thirteen-year time period, during which time there were extensive improvements to the cycling infrastructure. The analysis was conducted by looking at census results. The study showed that there was a 210% increase in cycling over the time period, and a clear correlation between improvements in the cycle network and increases in the usage of the facilities.

Statistical analysis was deemed as being unsuitable for the type of investigation that was desired for this thesis. Statistical analysis is mostly appropriate for analysing existing infrastructure and the proposed cycle route does not have any section that presently exists where statistical analysis could be performed. Completing statistical analysis on the study area would lead to misleading conclusions relating to cycling. There does not exist any significant section of cycle infrastructure along the proposed cycle route, upon which the statistical analysis could be performed.

Usage Surveys

It is important to understand what exactly constitutes a survey, in order to fully understand this topic. When one uses the word "survey", it means any form of collection of data by eliciting responses/preferences/opinions from a sample of respondents. There have been several studies that use this method for analysing cycling infrastructure.

Downward et al (2010), which was discussed in Section 2.4, would be an example of a usage survey. This survey was carried out amongst tourists cycling in the North of England. The results of this survey were used to identify important attributes for the tourist cyclists, and conclusions were formed from the personal demographic information given, in relation to the cycling infrastructure.

Akar and Clifton (2009) looked at the influence of people’s perceptions and cycle infrastructure on the decision to cycle, by means of a usage survey in the University of Maryland, in Washington D.C., USA. The respondents to the survey cited the lack of on campus bike lanes, as the most important reason for preventing them from cycling. Vehicular traffic on campus had a negative impact on the desire to cycle, as many respondents did not feel safe among vehicular traffic. People were more sensitive to time for non-motorised traffic, therefore if travel time decreases there could be a significant increase in cycling. It was found that decreasing the travel time by 10 minutes by bicycle, would increase cycling by approximately 6%.

Kemperman and Timmerman (2009) investigated various relationships between environmental characteristics, land use, and urbanisation on participation in walking and cycling amongst an ageing population. This study was conducted by means of a usage survey for those over 65 years of age in the Netherlands. Trip purpose was broken down into shopping (36.3%), social visits (18.6%), social/recreational trips (15.6%), and going for a cycle/walk (14.4%). The respondents were broken into four different groups. Groups were categorised as “Car Users”, “Bicycle Riders”, “Inactives” and “Walkers”. In general, older respondents who were over 72 are more inactive, with 44.9% belonging to the inactive segment.

Stinson and Bhat (2004) determined the most important factors affecting cycle commuting by means of an internet based usage survey. The results indicate that the most effective policy to increase cycling was to increase cycle parking at employment facilities. Cyclist training and education would also be an easy method of increasing cycling.

The methods discussed in Section 2.4.1 evaluate existing cycling infrastructure. The study under consideration in this thesis is concerned with a proposed cycling route in a particular study area. Therefore, the methods outlined in this section were discounted, as they would be inappropriate to use for investigating a proposed cycle route. Section 2.4.2 discusses evaluation procedures that can be used for proposed cycle infrastructure.

2.4.2 Evaluation of Proposed Infrastructure

This section outlines the methods that exist for analysing proposed cycling infrastructure, and can be used in determining whether proposed cycling infrastructure should be constructed or not.

Cost Benefit Analysis

Cost Benefit Analysis (CBA) first featured in infrastructure projects in France, in the 19th Century. The theory of welfare economics and CBA developed with micro economic theory, resulting in Pigou's "Economics of Welfare" in 1920 (OECD, 2006). Since then it has become regarded as the most appropriate method of determining the viability of different transport projects. CBA allows for the feasibility of different transportation projects, by expressing the cost and benefits in monetary terms, and provides a basis in which different projects can be compared. CBA is a logical method used to calculate and compare the benefits and the costs of a proposed project. This process usually results in a benefit to cost ratio, which indicates the return that can be expected from an investment. If the ratio is above 1, then the return is greater that the initial investment. If the ratio is below 1, then the return is less than the initial investment and the project should most likely be reconsidered. There have been numerous studies conducted using CBA.

Sælensminde (2004) completed a CBA of walking and cycling tracks, in Norway. This CBA took into account: the benefits of reduced insecurity, the health benefits of increased fitness, reduced air pollution and noise pollution, and reduced parking costs. The study concluded that the benefits accrued from this are estimated to be 4 to 5 times the costs of constructing cycle networks. CBA is usually used in the estimation of benefits from the construction of large scale infrastructural projects, such as roads and railways. Sælensminde (2004) determined that CBA is not appropriate in measuring the impacts of safety and mobility, which is particularly relevant for cyclists and cycling infrastructure. The CBA used in this study was adapted to measure the impacts of safety and mobility, but was based on high cost estimates and low estimates for the benefits, in order to prevent over-estimation. The authors believe that the adapted CBA method is adequate for use by politicians and other decision makers in Norway, for addressing cycling infrastructure.

In Ireland, the Department of Finance issued guidelines that indicate that CBA should be carried out on all government projects that exceed €30 million in value (Department of Finance, 2009). Simple assessments should occur on projects where the value is less that €0.5 million, and projects costing between €0.5 million and €5 million should have a single appraisal, with elements from both a preliminary appraisal and a detailed appraisal. Multi criteria decision analysis (multi criteria decision analysis is explained in Section 2.5.2.2) should be performed on projects valued between €5 million and €30 million. This document does not make reference to the use of CBA for cycle infrastructure projects. Furthermore, Browne and Ryan (2011) examined a number of policy evaluation tools, and found that CBA is useful in estimating the costs and benefits associated with transport policies, but is constrained by the difficulty of quantifying non-market impacts and monetising total costs and benefits.

It was determined that the current CBA methods would not be appropriate for the cycling infrastructure examined in this study due to the difficulty in estimating health benefits and other non-market effects. This study seeks to improve upon this difficulty of estimating health benefits and other non-market effects, and produce a method for cost benefit appraisal that can be accurately utilised for designing cycling infrastructure. However, before this can occur, the health benefits and the other non-market effects need to be analysed. Other methods for evaluating cycling need to be considered in order to achieve this analysis.

Multi Criteria Decision Analysis

Multi criteria decision analysis is a decision-aiding technique that may be used to integrate qualitative and quantitative information into a single assessment. This method can involve:

1. A given set of alternatives provided by the decision maker.
2. A set of criteria for comparing the alternatives.
3. The assigning of weights to criteria.
4. A method for ranking the alternatives based on how well they satisfy the criteria.

Looking at specific objectives of a decision maker, a group of impacts can be defined that capture the performance level of individual alternatives from a choice set. Browne and Ryan (2011) investigated how results from multi criteria decision analysis differed to results from CBA, from the same situations. It was found that multi criteria decision analysis and CBA differed regarding their outcomes. It was concluded that multi criteria decision analysis could be used in conjunction with CBA. Multi criteria decision analysis is most suited to decisions when it comes to policy, and CBA is most suited for transport infrastructure projects, where all the costs and benefits can be quantified.

Cordera (2009) developed a methodology for selecting routes for cycle paths using multi criteria decision analysis and GIS. This methodology was applied to the regional road network of Cantabria, in Northern Spain. It was found that a multi-criteria evaluation technique combined with the use of a GIS can be a simple, but useful tool for improving the planning process. This study determined it was best when choosing locations of cycle route construction, to give the highest weighting to closeness to settlement, followed by width of pavement. This indicates that closeness to higher populations is the most important factor, and the lowest weightings applied to average annual daily traffic, and the speed of traffic on the stretch of road. This methodology is dependent on large quantities of high quality data, for the conclusions to be accurate. This methodology is only useful for the construction of cycle facilities along an existing road, and would not be suitable for other design work with road design.

Multi criteria decision analysis was deemed inappropriate for the type of study in this thesis, as it is more focused towards policy creation. Multi criteria decision analysis has also been found to have different outcomes to other forms of analysis, performed in the same situation (Browne and Ryan, 2011).

Stated Preference

For the type of analysis considered in this study, there are two forms in which that the survey could be constructed. These are:

1. Revealed Preference Survey.
2. Stated Preference Survey.

A revealed preference survey refers to situations where a choice is actually made in real market conditions (stated preference surveys are discussed in Section 2.5, and revealed preference were discussed in the "Usage Surveys" part of Section 2.3). For example, if a passenger on a DART train in Dublin was to be surveyed, and the modes of travel available to them identified, it would be determined (revealed) that the respondent prefers to take the DART over the other transport modes. This would be a revealed preference survey. If the same person was questioned on their mode choice if the proposed Metro North line in Dublin existed, and how it would affect their journey on the train; which mode they would choose (state) in this hypothetical situation indicates their preferences. This would be a stated preference survey. By calculating how much each mode of transport costs, it is possible to calculate how much a person values their chosen mode of transport.

If a revealed preference survey was performed in the study area, it would only provide an indication of preference for existing cycling facilities. Presently, in the study area, there is very little cycling infrastructure provided, and there is no particular location where there would be a choice between different types of cycling infrastructure. The type of cycling facility proposed for the study area would be of a very high standard and nothing similar to this exists in the study area. Therefore, a revealed preference would not be appropriate for the analysis.

It became apparent while reviewing the evaluation methods that stated preference was successfully used in many instances. This process is the stated preference survey approach. The research from stated preference surveys is quite extensive, and is outlined in Section 2.4. A stated preference survey allows for greater detail to be included in the analysis over the previously outlined methods. A stated preference survey refers to situations where a choice is made by considering a hypothetical situation (Hensher et al, 2005). Stated preference surveys are especially useful in situations for considering choices among existing and new alternatives, as the latter cannot be observed in revealed preference surveys. Therefore, in circumstances where there are new infrastructural projects planned, stated preference surveys prove to be very beneficial in determining the choices of respondents. The stated preference approach is well documented and understood around the world. It is widely considered to be a good approach for investigating potential infrastructure. Generally, a combination of revealed preference and stated preference are used when surveying a population. This allows current habits and traits to be identified and outlined, and then, observations and analysis to be performed on the respondents hypothetical choices, if a new choice is introduced into the current choice set. The advantages or disadvantages of this new choice can then be quantified by investigating the data from the new choice set.

2.5 Stated Preference Studies and Cycling

This section details studies that have been conducted using stated preference and cycling. Having established that stated preference is the appropriate approach for analysing proposed cycling infrastructure, such as the route under investigation in the study area, it is critical to identify studies and projects where these theories were practiced.

Sener et al (2010) examined a comprehensive set of attributes that influence cycle route choice. This was done by using an online stated preference survey, in conjunction with a mixed multinomial logit model. The results of the paper concluded that cyclists have a preference for: minimal parking, continuous facilities, lower traffic volume and speed, and fewer intersections along a cycle facility. The survey also highlighted the sensitivity of a commuter cyclist's travel time. The results determined that a cyclist is willing to cycle approximately 6.21 minutes more or pay $1.26 to avoid parallel parking on their commute route.

Stinson and Bhat (2003) determined the variables, which affect a cyclist's route choice from an analysis of commuter cyclists using a stated preference survey. The paper concluded that the six most important factors in order of importance were: lower travel times, road classification, type of cycle infrastructure, barriers between motorists and cyclists, pavement quality, and fewer intersections. These qualities varied from commuter to commuter. The main causes of the variances were attributed to a commuter's age, and residential location.

Tilahun et al (2007) conducted an investigation into how people who cycle value varying standards of cycling facilities, by means of a stated preference survey. The types of cycling infrastructure presented to the respondents of the survey were: Off-road facilities, in-traffic facilities with bike-lane and no on-street parking, in-traffic facilities with a bike-lane and on-street parking, in-traffic facilities with no bike-lane and no on-street parking and in-traffic facilities with no bike-lane but with on-street parking. These facilities were presented to the respondents with indicative images accompanying each option. The study found that respondents were willing to pay most for the off-road cycling facility, with respondents willing to pay up to 20 minutes to switch from the other options to the off-road facility.

Wardman et al (2007) analyses the factors that influence the propensity to cycle to work in the UK, by means of a stated preference survey. The models created from this dataset predict that improved en-route and at work facilities, will only have a minor impact on the cycling rate for commuting. The models showed that when there is a direct financial stimulus, such as a financial payment to those that commute by bicycle, there is a considerable increase in those that are predicted to cycle. The models displayed that when there is a package of improvements (such as financial incentives, improvements to en-route cycling facilities, improvements to at work facilities, etc), there is considerable scope for increasing the cycling rate for commuting, and decreasing the driving rate.

Hopkinson (1996) carried out a study on evaluating the demand for new cycling facilities in Bradford. The results from the survey concluded that safety was the most important aspect to be considered, when designing new cycling infrastructure. It was identified that the construction of some cycling infrastructure could be economically justified solely from the benefits accruing to those that are currently cycling. It was found that improved cycling infrastructure could lead to transport mode switching and generation, as well as route switching.

One must be wary of biases in using stated preference surveys, as what a person says they will do and what they actually do sometimes does not corroborate. Bonsall (2009) investigates how effective political policies are in relation to sustainable travel behaviour, and what particular problems need to be overcome. It was concluded that no single technique can be relied on to give an unbiased point of view, and biases that occur when surveys are being undertaken, can lead to exaggerations in the estimates of likelihood of behavioural change, in response to sustainability concerns. It was found that the usage of data from a variety of sources is unlikely to suffer from the same biases.

On reviewing the literature, it became evident that there is no clear approach for analysing proposed cycling infrastructure. Each method could be utilised but would be restricted due to methods that do not include certain aspects, such as health, and other non-market effects. A stated preference survey was deemed to be the most suitable method for the analysis in this thesis. Stated preference surveys are ideal for investigating potential infrastructure. Combining a stated preference survey with a revealed preference survey seemed the most suitable option for this study, as the potential increase in cycling from the construction of a cycle route could then be calculated. The results of this stated preference survey can then be utilised in further analysis of the proposed cycle route.

2.6 Health and Economic Benefits of Cycling

Much of the benefits derived from cycling ties into health. It was therefore essential to review the literature involving cycling and health. It is well documented at both government and academic levels, that cycling has a very positive impact on both personal health and the public health system. Many of these studies conclude that any form of an increase in the cycling mode share for commuting and for other purposes, would cause corresponding improvements in the health of an individual who cycles. This also results in an increase in the health of a country as a whole, where there is a reduction in the mortality rate of the population who cycle. From the WHO (2011), it is known that physical inactivity in the world is one of the leading causes of ill health. The promotion of active travel behaviour is a “Win-Win” approach, as it not only increases the everyday activity of individuals; it also has a positive impact on the environment. The WHO found that there was huge potential for active travel in the World, as there are many journeys carried out by the automobile, that could very easily be achieved either by bicycle or by walking. Many academic studies have been completed that correlate increased cycling with improvements to health. Many of these studies can be viewed in this section (WHO, 2011).

Cavill et al (2008) found that physical activity was a fundamental way of improving the mental and physical health of individuals; however there are many instances where a lack of daily physical activity can have negative health consequences. Cavill et al (2008) demonstrated how increased physical activity leads to a reduction in cardiovascular disease, stroke, cancer, and type II diabetes. Increased activity can also lead to a reduction in anxiety and depression. Therefore cycling for commute purposes presents a very practical opportunity for improvement in one’s health. Rojas-Rueda et al (2011) and de Hartog et al (2010) both found that the gains in health because of increased activity from a higher level of cycling, far outweigh the potential negatives, from the increased risk of a traffic accident and the increased exposure to pollution.

Anderson et al (2000) documented 13,375 women and 17,265 men over a 14 and a half year period. Over this period 2,881 women and 5,668 men died. This research found that those who cycled to and from their places of work and education had a 40% reduction in their mortality rate. This reduction in mortality rate was the same for both men and women, with no statistically significant difference between the genders.

Mindell et al (2011) showed how various different transport modes affect human health, in an urban environment. It was found that the benefits of transport (access to work, leisure, education, social contacts) was most experienced by the healthy and the affluent, whereas the harmful effects (air pollution, community severance, injuries) of transport are mostly experienced by the poor, young and old in society. It surmised that a modal shift away from cars, in favour of walking and cycling would reduce the harmful aspects of transport and improve the health of individuals in society. The environment and society would also benefit.

Gerber et al (2013) investigated the levels of absenteeism amongst cyclists and non-cyclists. It was discovered that those who cycled to and from their places of work had one day less of absenteeism per year, than those that did not cycle. The authors believe that this reduction is due mainly to the better health of those that cycle, and results in a financial gain for an employer.

Unwin (1995) found that there was a very large potential for improvement in the health of British males from increasing levels of cycling. It was found in a study of male civil servants that regular cyclists (those who cycled for at least an hour every week) had less than half the coronary attack rates than non-cyclists.

Garrard et al (2011) outlined the health benefits of cycling in Pucher and Buehler's (2011) City Cycling. Garrard et al (2011) identified the key health benefits that have been replicated across the globe from increasing cycling rates. For physical health, increased cycling can advance the prevention of chronic diseases, and has favourable impacts on associated risk factors. It was found that the energy expended by cycling for a certain period of time, is roughly twice that of walking for the same period of time, and therefore it is better for a person's health. The non-physical health benefits could be categorised into three groups.

This section showed that there is unquestionably a positive increase in health, where there is an increase in cycle rates. It was observed however, that no text to date quantifies financially these benefits. This was identified as an area where there could be large improvements. The WHO released a tool that analyses the health impacts for cycling in 2011, and this presents a very interesting opportunity to create a case study using this tool. The tool is discussed in Chapter 4 and Chapter 7. To the best of the author's knowledge, no academic research has been published that utilises this tool.

2.7 Cycling for Tourism

It became evident in Section 2.2 that the research involving cycling was restricted mostly to commuters, and where usage other than commuters was investigated; it was mainly in an urban context. The areas of cycling for tourism and recreational cycling, and cycling in a rural context, have not been the focus of any investigation.

It was decided to look at the research that has been conducted into cycling for tourist purposes around the world. It was found that presently, research into cycling and tourism has not been overly developed. Research has, in the areas of sports and cycling tourism, mainly focused on hallmark events where people travelling for sports tourism are spectators. These landmark events mainly consist of sporting tournaments that range in size from small scale (local sports teams competing), medium scale (national sporting leagues in a country); to large scale (Olympics, World Championships). Hinch and Higham (2011) demonstrate that sports tourism is composed of three main areas. These are as follows:

- Hallmark events.
- Outdoor recreation.
- Health and fitness.

Landmark events are extensively analysed in Hinch and Higham (2011). Hinch and Higham state that outdoor recreation is, "an area that is inextricably linked to sport tourism" and that "One of the most dynamic components of outdoor recreation is adventure tourism". Ritchie (1998) found that globally, cycling for leisure, recreation and tourism has been re-emerging since the 1990s, and that the relevant cycling industries' interest in the area at the time was scarce. It was found that there was not any demand related literature in relation to cycle tourism. In order for this area of tourism to grow appropriately, and contribute to the economic and social well being of a rural area, the demand and supply side of cycle tourism needs to be further researched and fully understood. Lamont (2009) examines literature, both at an academic level and a government level, from around the world that analyses cycling tourism. It was found that defining cycling as a “strictly recreational phenomenon may be overly restrictive”. This paper defines tourist cycling as:

- Persons who travel away from their home region, of which active or passive participation in cycling is the main purpose for that trip.
- Persons who travel for the purposes of engaging in competitive cycling, and those who travel to observe cycling events.

In 1999, Sustrans published a report on cycling tourism in the United Kingdom. Sustrans is a UK charity that endeavours to make sustainable travel by foot, bicycle and public transport more attractive (Sustrans, 1999). Sustrans (1999) found that cycle tourism was worth £695 million to the UK economy annually. This report found that it was important to develop cycle tourism as:

1. Cycle tourism is positive at generating local trade and offers business opportunities, particularly in rural areas.
2. It is an environmentally sustainable form of tourism with minimal impact on the environment and can help reduce traffic congestion.
3. It utilises existing facilities and often under-used facilities such as quiet laneways, and canal towpaths.
4. It can provide a use for disused railway lines.

This Sustrans report also conducted several case studies into cycling infrastructure that catered predominantly for tourists. One such case study was the “C2C Cycle Route” in Northern England. The investigation found that the average daily spend of a user was £30, and that 76% of the expenditure was in local businesses such as pubs, restaurants, cafes and accommodation. In 1997, the expenditure by C2C users was £1.1 million. In order to grow this market, the report established that it was necessary to create:

1. Safe, convenient, and attractive cycle routes that cater for both long and short distance cycling.
2. Safer and easier access points into and out of cities and towns.

3. Cycle routes that have as little interaction with vehicular traffic as possible, so as to reduce the perceived danger from passing traffic.

Hinch and Higham (2011) discuss how the development of sport related leisure services is one successful approach that can be used to reimage a place. In order for sport tourism to develop at a destination, resources and infrastructure that cater for the targeted sport and tourism must exist. These resources and infrastructures need to be planned and provided in a balanced and coordinated way, with the development goals of the location. Coordination is important, as there can be a large overlap between resources for sport and those for tourism. Another project that is similar to the "C2C" in Northern England is the Munda Biddi trail in Australia. The Munda Biddi trail is presently 1,000km long (Munda Biddi Foundation, 2012). The trail is in a predominantly rural location and passes through several small towns. It is constructed along forest tracks and disused railway lines. The trail enjoys 21,000 visitors annually; the majority stay for three days along the route. This leads to a demand for accommodation, cycle hire, food and transport in the towns located along the route. It is estimated that in 2013, the Munda Biddi Trail will bring AUD$13 million into the South West and Great Southern communities of Australia (Munda Biddi Foundation, 2012).

A detailed analysis of stated preference survey and tourism was conducted. It was identified that to the best of the authors knowledge, that there has never been a stated preference survey on cycling involving tourists. The closest study identified by the author to the analysis desired for this study was Reilly et al (2010). Reilly et al (2010) performed intercept surveys on tourists in Whistler, British Columbia, in order to collect information on their travel behaviour and to form a basic visitor profile. It was found that tourists, who travelled furthest, were most likely to change their transportation choice towards a more energy efficient mode. This paper looked at the shift towards more sustainable transport, which in this instance was public transport. Cycling was not included in the sustainable transport considered by the tourists; however, the paper demonstrates willingness by tourists for more sustainable transport options. The intercept survey had 1,643 responses. In the intercept survey, email addresses of the respondents were collected, and a further

467 people completed a more detailed online survey containing a stated preference section. The research objectives were very similar to the objectives that the authors of this paper set at the start of this paper. Reilly et al (2010) used a fractional orthogonal factorial design (fractional orthogonal factorial design is discussed in the Chapter 4) in the formation of scenarios that were presented to the respondents in their survey. This method was deemed by the author to be the most appropriate method by the authors from which the dataset could be formed.

As was mentioned in this section, to the best of the author’s knowledge, there does not exist stated preference study carried out amongst tourists in the area of cycling. This lack of literature indicated that there was a need for some analysis in this area. Following the review of research into tourism, another area that required attention was cycling for recreational purposes.

2.8 Cycling for Recreation

For several decades, cycling for recreation received very little attention in academic research. It is only in recent years that attention has shifted away from solely focusing on cycling for commute purposes, towards cycling for other purposes. It can be seen in Section 2.6, that it is only in the past decade that cycling for tourist purposes began to be researched at an academic level.

Badland et al (2013) sought to examine the uptake of cycling for recreation and transport, and relate these to the behaviours of individuals’ social and environmental exposures over time. It was determined that cycling interventions (construction of cycling facilities) should be considered differently, for cycling intended for recreational purposes, and for cycling for transportation purposes. It was found that cycling interventions that focused on enhancing self-efficacy and generating social support, led to a positive influence on cycling for recreation and transport. Providing infrastructure that creates physically supportive neighbourhoods increased cycling levels.

Xing et al (2010) investigated the factors that affect cycling for recreation and transportation in six cities, in the USA. It was determined from an online survey in these six cities that individual, social environment, and physical environment factors have the strongest effects on the balance between transportation and recreational cycling, and on distance of cycling for each purpose. Cycling comfort and an aversion to driving were associated with increases in transportation cycling. Cycling facilities played an indirect role in the perceived safety of cycling, and attracted more people to cycling. The study discovered that in order to increase cycling for transportation purposes, it is important to increase the levels of recreational cycling. It was found that cycling rates for transportation and recreational purposes could be increased by expanding cycle networks, and by providing cycling infrastructure that improves cycling safety.

Gobster (1995) conducted intercept surveys of recreational cyclists along thirteen greenways in Chicago, Illinois, in the USA. This was completed so as to develop further factors that influence the success of a greenway network (at the time of writing this paper, distance and connections were the main factors considered in the design of greenways). It was demonstrated that vegetation management, trail surface, and the maintenance of the greenway were very important factors for recreational cyclists. It was identified that from a recreational cyclists' perspective, for metropolitan areas, that "Local" (short to medium distance) trails should form the basic framework of a metropolitan greenway network, rather than "Regional" (medium distance) and "State" (long distance) trails. It became apparent in this study that location, maintenance, and management decisions should be factored in during the design process of greenways.

Goosen and Langers (2000) assessed rural areas in relation to recreational activities in the Netherlands. For this, quality was split into two categories; utilisation quality and perceived quality. Utilisation quality is the fitness of purpose for use, and the perceived quality is the quality of the environment which people notice or experience (such as beauty of the landscape or the tranquillity). For cycling, it was found that 12% of the areas where recreational cycling occurs regularly were rated as good for cycling, and 56% were rated as reasonable. Only 6% of the areas where recreational cycling occurs regularly were rated as poor in quality. By understanding how the quality of areas where recreational cycling occurs and how this quality is affected, allows for better planning and design of future cycling facilities, where the primary aim is recreational. This will allow for any new cycling infrastructure meant for recreational cyclists to be of a higher quality.

Christie et al (2010) sought to value a range of improvements of recreational facilities in forest and woodland areas, in the UK. This research targeted cyclists, horse riders, nature watchers and general visitors to forests, by means of an intercept survey. It was found that within these groups there were varying degrees of willingness to pay, for different facilities. It was identified that downhill mountain bikers were willing to pay more for the provision of specific downhill courses, while family cyclists were willing to pay for easy cycle trails. For modelling the responses of the cyclists, four different models were created.

From this review of tourist and recreational research involving cycling, it can be observed that there is a significant demand for infrastructure that caters for these purposes. However, to the best of the author's knowledge, there does not exist any research that ascertains how these groups value or perceive different standards of cycling infrastructure. For example, the question of, "Is a recreational or tourist cyclist willing to divert or increase their travel time in order to cycle upon better quality cycling infrastructure?" has not been addressed in any literature. Other questions of "How do the preferences of tourists, recreational users, and commuters differ when it comes to cycling infrastructure?" have also never been addressed. These issues led the author to the conclusion that this area needed to be better addressed and consequently resulted in this study.

2.9 Summary

On reviewing the existing literature in the areas of cycling, there were several stand out aspects that appeared to require more attention. The areas identified for more research are outlined as follows:

1. From reviewing the existing research undertaken in Ireland and around the world, it became obvious that cycling in rural areas is presently under researched. When compared to the research conducted into urban

cycling, there is very little information into rural and interurban cycling available. It was also recognised that the attributes that affect cycling behaviour in Ireland have never been fully determined. These attributes vary from country to country and it is important that these be fully understood, in order to understand a cyclist's behaviour.

2. It was evident from the restricted nature in the research in cycling for tourists and for recreational purposes that this area would benefit, by identifying how exactly the preferences for these two categories differ to commuters, and identify how the willingness to pay of these groups vary for different standards of cycling infrastructure.
3. It was apparent that there was a serious lacking in the published academic literature, in quantifying financially the economic benefits from investing in cycling infrastructure. The WHO released a tool for estimated the economic health benefits from cycling in 2011, and there is yet to be a case study with the application of this tool.

Having identified the gaps in the current literature, Chapter 4 describes the theories and analysis of the stated preference survey and the health economic analysis tool.

3 Case Study and Initial Scoping Survey

3.1 Introduction

The purpose of this chapter was to better understand cycling and cycling infrastructure. This chapter presents the results of two preliminary studies that were undertaken before the stated preference survey, and the health economic analysis were completed. The purpose of the case study was to obtain a better understanding of greenways and the usage patterns, and to develop a methodology from which the stated preference study could extend. This study also highlighted certain areas of cycling infrastructure research that required further attention.

The purpose of the scoping survey was to better understand the perceptions and opinions of people, in relation to cycling infrastructure in Ireland. There are many aspects of cycling trips that could be analysed. It was imperative that the aspects of cycling that were investigated were the most relevant. For this survey, respondents were asked to rank various attributes in relation to cycling. The highest ranked attributes were carried forward for usage in the stated preference study.

3.2 Case Study of Greenway in Ireland

This section describes the case study that was undertaken on a greenway in the North West of Ireland. This case study acted as an initial investigation into this type of infrastructure in Ireland, and highlighted where the subsequent analysis should be conducted in this thesis. The results presented in this section are based upon the work published in Deenihan et al (2013).

3.2.1 Introduction

One of the objectives of the National Cycle Network Scoping Study were to promote the development of walking and cycling in Ireland. One objective was to "*Provide designated rural signed cycle networks providing especially for visitors and recreational cycling*" (Smarter Travel Office, 2009). One such project is the Great Western Greenway in the North West of Ireland. The first phase of this project, an 18 km route from Newport to Mulranny, was opened in April 2010. This phase was a "huge success" (Fáilte Ireland, 2010) and a €3.5 million package was agreed to expand the route to 42 km. The 42 km route is currently the longest off-road cycling and walking trail in the Republic of Ireland.

In 2009, it is estimated that cycling tourists spent €97 million while in Ireland (Fáilte Ireland, 2009). Fáilte Ireland (2009) also surveyed cyclists in Ireland. It was found that many of the cyclists that were surveyed were satisfied with cycling in Ireland, however; 12% of those surveyed were either dissatisfied or very dissatisfied. With investments in infrastructure like the Great Western Greenway, it is hoped to increase the percentage of cyclist tourists that are satisfied with cycling in Ireland. This in turn may lead to an increase in expenditure from this category of tourist, and also increase sustainable travel patterns within the area. Lamont (2009) claims that there has been a relationship between cycling and tourism since the 1890s, and that only in recent years, is this area being researched academically. It is important that research be carried out in this area, as the lack of knowledge leads to misleading conclusions when categories of tourists are not defined properly. This can mean falsification, exaggeration, and an understatement of facts, when it comes to the analysis of certain cycling groups. Burkart and Medlik (1981) also state why it's important that research into tourism be carried out. It is necessary for three specific reasons. They are as follows:

1. To evaluate the value and significance of tourism to a particular area.
2. To use in the design and planning of infrastructure and service for tourists.
3. To plan and create effective marketing campaigns.

The research presented in this section examines the usage of the Greenway. Several similar projects of this nature are currently under consideration in Ireland, such as the proposed cycle route in the study area indicated in Chapter 1. In order for the proposed cycle route to be successful, it is critical to better understand these particular types of cycling infrastructure. See Figure 3-1 displays a sample section of the Great Western Greenway. This section analyses counter data in relation to weather parameters, and also evaluates the benefits users of the Great Western

Greenway bring to the area. The Great Western Greenway benefits locals in that it caters for safe sustainable travel within the area and also provides them with a leisure/fitness route. The economy benefits as this delivers an attractive facility for tourists, and therefore encourages tourism into the local area and Ireland. There are numerous health benefits in terms of increased exercise for people utilising the facility, and hence decreasing health expenditure. Infrastructure such as this promotes cycling positively, by providing a facility that will allow a potential cyclist commuter to experience the benefits of cycling, in an attractive safe environment.

Figure 3-1 Image of Great Western Greenway in Mayo, Ireland

Source: Discover Ireland (2010)

Figure 3-2 illustrates the location of the Great Western Greenway in a national and local context. The top map indicates the area surrounding the Great Western Greenway in regard to the county. The bottom map displays the route of the Great Western Greenway in green, and the parallel Primary road is indicated in red. The routes are illustrated in the context of the surrounding area. Settlements along the route are indicated in black. The greenway traverses ten electoral wards and from the 2006 census of Ireland statistics, the population density in each electoral ward is known. This is indicated by the purple dots, with each dot representing one resident. Other roads in the area are displayed in green. It can be seen that the population in the eastern and southern sections is denser than the western sections. The Great Western Greenway is similar in nature to the Munda Biddi Trail in Western Australia that is discussed in Section 2.7 of Chapter 2.

The population in the area surrounding the Great Western Greenway from the 2006 Census is 4,967 (Central Statistics Office, 2007). A Table of statistics for the area can be viewed in Table 3-1. These census figures were compiled in 2006, four years before the first phase of the Great Western Greenway opened. Table 3-1 indicates that there are more males in the area than females, the car is the predominant means of transport, the age group ‘35 – 49 years’ is the largest age group and 45.5% of household have two cars.

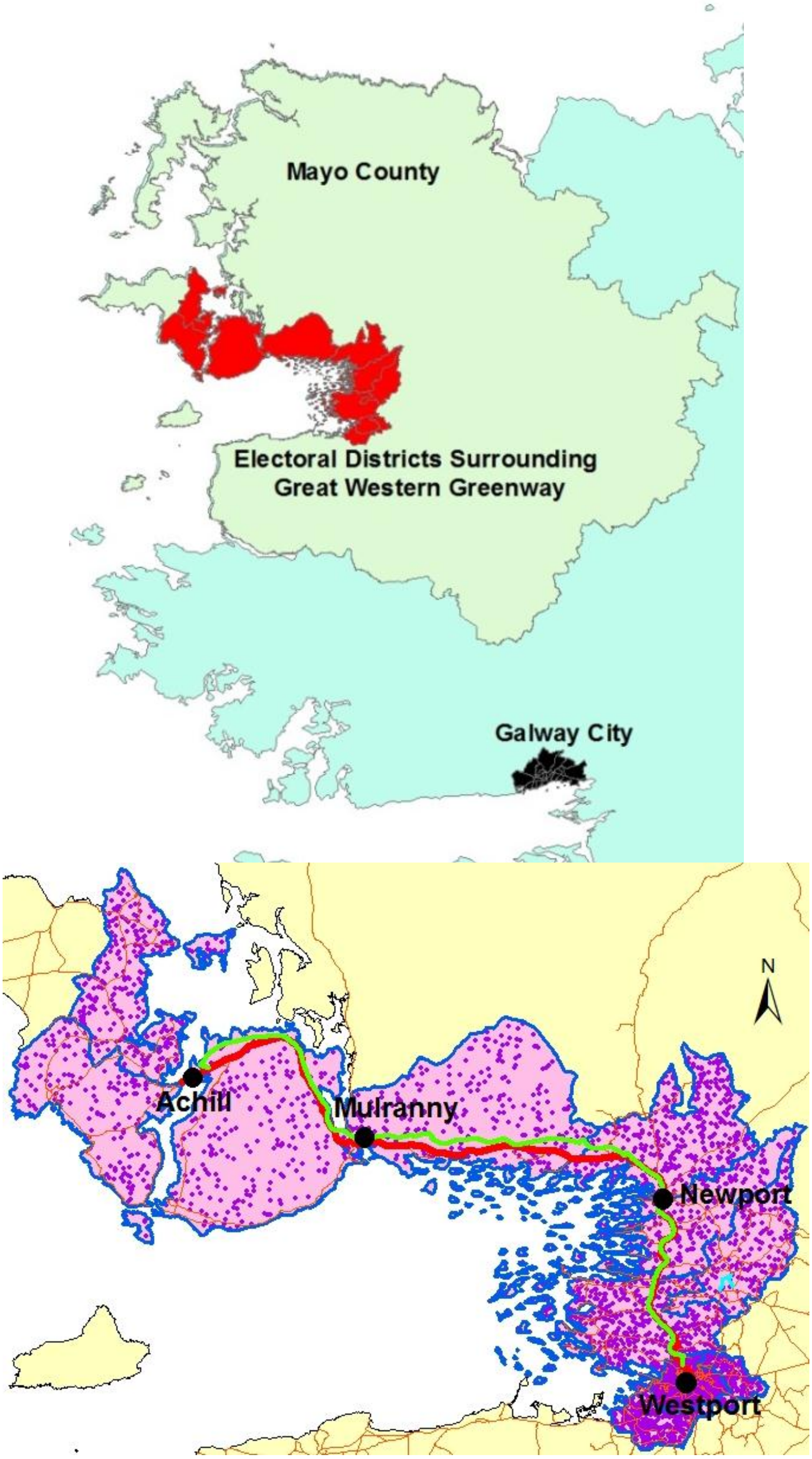

Figure 3-2 Maps Indicating the Location of the Great Western Greenway. Population Density Represented by Purple Dots in Lower Map

Table 3-1 2006 Census Statistics from the Local Area Surrounding the Greenway

Category	Number	Percentage
Gender		
Male	2,801	56
Female	2,166	44
Total	4,967	100
Means of Transport		
Walk/Cycle	765	15
Bus/Rail	50	1
Car	3,193	65
Work from Home	169	3
Other	790	16
Total	4,967	100
Age		
15 – 24 years	581	12
25 – 34 years	1,272	26
35 – 49 years	1,833	36
50 – 64 years	1,167	24
65 + years	114	2
Total	4,967	100
Cars in Households		
No Car	318	6
1 Car	1,585	32
2 Cars	2,260	45
Three Cars	576	12
Four or More Cars	228	5
Total	4,967	100

3.2.2 Methodology for the Data Analysis

This section outlines the theory behind the analysis that was conducted in the case study. During construction of the Great Western Greenway, several Sierzega Bike counters were installed along the route. At the time of the case study, only two of these counters were active. The two counters were located adjacent to the settlements of Achill and Mulranny, and are approximately 12 km apart. This data is used in conjunction with weather data. Rainfall, mean wind speed, and mean temperature measurements were retrieved from an automatic Irish Meteorological Service weather station, located in Newport. Sunshine hours were recorded at an Irish Meteorological Service Weather observatory located in Belmullet, approximately 35 km away from the locations of the counters. The various weather parameters and the user figures can be correlated. Determining these relationships allow predictions of usage along the path according to weather forecasts. Regression analysis was also performed on the data, allowing conclusions regarding the effects of weather on usage to be determined. This regression analysis was similar to the analysis performed by Levitte (1999).

Multinomial logit regression model was estimated in this research. Multinomial logit regression has been used widely for this type of research. Reilly et al (2010), Caulfield (2013), Sener et al (2010), Tilahun (2007), and Wardman et al (2007) utilised multinomial regression analysis on similar usage results to determine relationships between attributes, choices and the respondents.

The choice variable examined in the model was the usage of the Great Western Greenway. There were four levels of usage with two levels above the daily average usage of the Great Western Greenway and two levels below. “1” represents low usage, “2” represents above low-medium usage, “3” represents above medium-high usage, and “4” represents high usage. Within the model the referent variable is “4”. The model examined the impact of the weather parameters: temperature, rainfall, mean wind speed and sunshine hours on the usage of the path. Each weather parameter was split into four sub-categories, each representing a quarter of the total for that parameter. A multinomial logistic regression analysis was constructed to analyse the relationship between these factors and the usage of the Great Western Greenway. The model takes the following functional form:

Equation 3-1

$$\text{logit}(p) = \log\frac{p}{1-p} = \alpha + \beta I + e$$

where *p* is the probability that event Y occurs (decision to use the Great Western Greenway), *βI* is the set of weather parameters, and *e* is a random error term. Table 3-5 details each of the weather parameters estimated and the resultant model.

The counters are based on radar technology and record: time, date, speed, and direction of the cyclist passing. The device operates by measuring the length of a passing object. The device is able to split larger objects into several shorter objects. For instance, if several cyclists pass at the same time, the software can determine from the length recorded, how many cyclists are in the group. If the cyclists are in a group, side by side, the whole mass of the group will be longer than one cyclist. The device has been calibrated from extensive studies of cyclist groupings, to determine the quantity of cyclists that would be in a measured group. This is not 100% accurate and may vary for certain conditions, however, accuracy is high with recorded speed being accurate to +/-3%, and length measurement of passing objects being accurate to +/- 20% (Sierzega, 2012). The data recorded allowed many observations to be carried out such as: average daily usage, average hourly day profiles, weekend and weekly usage. The data alone reveals many patterns and noteworthy observations.

3.2.3 Counter Data Results and Analysis

The data from one of the cycle counters can be viewed in the charts in Figure 3-3. External factors such as weather, time of the year, and days of the week were investigated as to how they impact upon usage of the greenway. Over the period recorded, there were several national holidays, and periods of good and poor weather. These external factors were noted and the relationships between usage and these factors were observed. The information contained in Figure 3-3 is over a period of 566 days (2011–2012).

Firstly, the daily numbers were compiled for the counter and the usage was plotted over time. Three models were created from the daily numbers. These models were:

- All year model.
- Summer model.
- Winter model.

The all year model contains all the data. The summer model contains the data from the 1st of April to the 31st of September, whereas the winter model contains the data from the 1st of October to the 31st of March. Trend lines were inserted into the data to determine if there were any particular patterns observable and whether certain times of the year are busier than others (see Figure 3-3).

The averages for each hour of the day were calculated for all days, weekend days, and weekdays, for the three different models. This allowed an average hourly day profile to be created for the three models, and different usage patterns between weekdays and weekend days to be observed. The charts created indicate that weekdays and weekend days carry approximately similar quantities over the course of a day, but vary at different times. From these models, Table 3-2 was formed with the expected numbers between the hours of 6:00 and 22:00.

Table 3-2 Average User Numbers

		Average Daily Numbers
All Year Model	**All Days**	471
	Week Days	450
	Weekends	494
Summer Time Model	**All Days**	488
	Week Days	476
	Weekends	518
Winter Time Model	**All Days**	363
	Week Days	354
	Weekends	385

Table 3-2 illustrates how the usage patterns change depending on the time of the year. There is approximately a drop of 100 users on the path on average per day between the summer model and the winter model. The table also illustrates how usage increases for weekends. There is estimated to be an increase of 30 to 40 users on average at the weekends compared with weekdays.

The first chart in Figure 3-3 illustrates the changing nature of usage along the Great Western Greenway over the course of a year. It can be seen how the usage is seasonal in nature, as there is a peak in usage in the summer and a trough in usage in the winter. It can be seen how there is an upwards trend in usage for the first half of the year, with usage peaking in August. From the peak in August to the end of the year, there is a downward trend in usage. The average daily usage at different times of the year varies from just over 100 users a day in December and January, to over 400 users a day in August. The trendline used to fit on the data in the chart has an R-squared of 0.174. This low R-squared value can be attributed to the non-parametric nature of the data, with usage varying greatly from month to month. The second, third and fourth charts in Figure 3-3 illustrate how the profile of the daily usage varies depending on the season. The second chart displays the average hourly usage profile between the hours of 6:00 and 22:00 for every day of the year. The third and fourth charts display the same except that the third chart displays only the results from analysis on summer data, whereas the fourth chart displays only results from the winter data. By displaying the data as such, it can be seen how usage varies at different times of the year and also for different days of the week.

All the charts have a morning peak Monday to Friday between the hours of 7:00 and 9:00. The summer time model has a smaller peak in the morning than that of the winter model. It is believed the reason for this is that the schools, along the route, are out of term and therefore there would not be any students using the Great Western Greenway, to commute to and from school in the mornings and the afternoon. All models have a peak at 13:00/14:00. The counter is located adjacent to a very scenic village that would be popular for lunch. It is believed that many recreational users plan their journey with lunch at this village in mind.

The winter usage profile is smaller than the summer profile, because as stated previously, there are fewer users along the path in winter time than in summer. For Monday to Friday, the winter usage profile has very much a commuter profile appearance, with users most likely commuting to and from school and places of work in the morning and evening time. These users are believed to be mixed with recreational users, as there is consistent usage throughout the day and a plateau shape in evening time until 20:00. The weekend usage profile for the winter model is of a more recreational usage shape with a small morning peak, increasing until 13:00 and then peaking again at 17:00.

The summer usage profile contains a less pronounced morning peak. As stated previously, this is probably mainly due to the schools being closed for summer holidays. The summer model profiles for both weekdays and weekends are very similar shapes, except that the weekends have a very pronounced increase and plateau after 14:00. It is believed that the majority of users over the summer months are recreational users, with usage peaking in the afternoon time, particularly at the weekends.

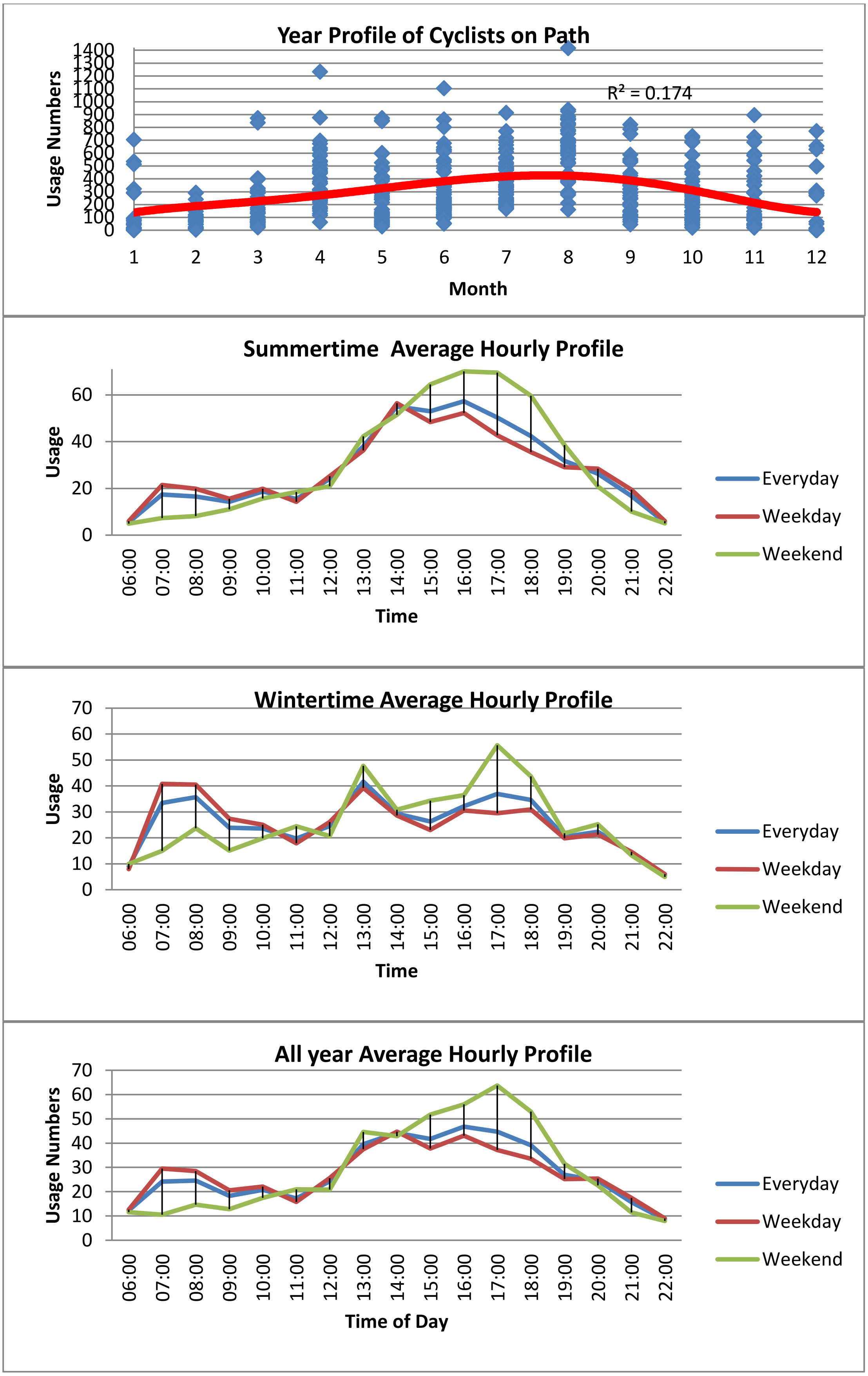

Figure 3-3 Charts Containing Usage Data

3.2.4 Benefits of the Greenway

The overall cost of the Great Western Greenway was approximately €5.7 million (National Trails Office, 2012). The current economic crisis in Ireland has led to decreased spending on infrastructural projects, and as a result it is important that only projects that provide the greatest return to the state go ahead. Therefore, determining the value of this project would provide a clear indication of whether similar projects should go ahead. Working on the assumption that usage of the Great Western Greenway was to continue at the same level of usage, Table 3-3 was created. The usage data in Table 3-3 comes from the Mulranny counter in order to prevent double counting of users who may travel along the entire length of the Great Western Greenway. The results in Table 3-3 indicate that the increased spending by tourists in the local area alone would justify the construction costs of the Great Western Greenway.

Fáilte Ireland commissioned a report by Fitzpatricks consultants in the summer of 2011 (Fitzpatricks, 2011). This report found that approximately 8,000 of the users were non-domestic tourists, spending on average €50.71/day while cycling the Great Western Greenway. The report also found that there were 14,800 domestic tourists cycling the Great Western Greenway, spending on average €49.85/day. From Table 3-3, it can be estimated that after a 6 year period, the facility will have returned the initial investment from solely tourism revenue.

Table 3-3 Quantifying the Benefits of the Greenway

Usage over a 1 year period		172,000 trips	
Usage over a 10 year period		1,720,000 trips	
Cost of construction of Great Western Greenway		€5.7 million	
Maintenance per annum		€40,000	
Total cost to local area over 10 years		€6,100,000	
Cost per trip over a 10 year period		€3.55	
Assuming that the usage figures neither rise nor decline over a 10 year period, and that a tourist is only cycling along the Great Western Greenway for one day			
Domestic tourists		**Non domestic tourists**	
Total numbers	14,800	**Total numbers**	8,000
Spending in area over a year	€737,780	**Spending in area over a year**	€405,680
Cost of these trips	€52,540	**Cost of these trips**	€28,400
Spending after cost for the local area	€685,240	**Spending after cost for the local area**	€377,280
Total spending in area from tourists minus the cost per trips, per year		€1,062,520	
Over a 10 year period		€10,625,200	
Payback period		6 years	

3.3 How weather affects usage of path

Weather patterns are measured at an automatic weather station in Newport. This was the closest weather station for the entire route. The data from the station was corroborated with the usage data from the counters along the Great Western Greenway, and regression analysis was performed. Graphs with weather records and user data imposed can be viewed in Figure 3-4, and the tables containing the results of the multinomial logistic regression analysis can be viewed in Table 3-5. These graphs indicate relationships between weather and the usage of the path.

From the data retrieved from the counter, it can be seen in Figure 3-4 that usage of the path is inversely proportional to the rainfall and the mean wind speed, and that there is a positive relationship between temperature and usage.

When rainfall over the course of a day is 0mm, the average usage for that day will generally be over 300 users, and when rainfall is over 10mm the usage will generally be below 200 users. When the average temperature over a day is below $5^{o}C$, the average usage will generally be below 200 users and when the average temperature is above 15 ^{o}C, the usage is generally above 400 users. When the mean wind speed over a day is below 10 knots the average numbers passing along the Great Western Greenway that day is generally above 300 users and when mean wind speed is above 20 knots, the usage is generally below 200 users.

In order for these relationships to be analysed effectively, it is necessary to perform multinomial logistic regression analysis on the data. The three models mentioned previously (All year, summer, winter) were used in this analysis. Within these models the usage numbers, rainfall, mean temperature and mean wind speed, were split into quartile groups. These groups were categorised as low, low-medium, medium-high and high and were categorised as 1, 2, 3, and 4 respectively. Multinomial logistic regression analysis was performed on these categories, with usage as the dependent variable. These continuous variables are categorised in order to create a better prediction model. The group quartile values within each of the three models can be observed in Table 3-4.

Table 3-4 Variables and their Quartiles

Group	Quartile	Cate-gory	All Year Model	Summer Model	Winter Model
Usage (Users)	1st Quartile	1	Less than 119	Less than 236	Less than 46
	2nd Quartile	2	119 to 290	236 to 290	46 to 136
	3rd Quartile	3	291 to 437	291 to 481	137 to 150
	4th Quartile	4	More than 437	More than 481	More than 150
Rainfall (mm)	1st Quartile	1	Less than 0.2	Less than 0.1	Less than 0.375
	2nd Quartile	2	0.2 to 1.69	0.1 to 1.19	0.375 to 2.49
	3rd Quartile	3	1.7 to 5.3	1.2 to 3.8	2.50 to 6.7
	4th Quartile	4	More than 5.3	More than 3.8	More than 6.7
Mean Temp-erature (^{o}C)	1st Quartile	1	Less than 8.45	Less than 11.2	Less than 6.55
	2nd Quartile	2	8.45 to 10.99	11.2 to 12.99	6.55 to 8.69
	3rd Quartile	3	11 to 13.44	13 to 14.4	8.7 to 10.1
	4th Quartile	4	More than 13.44	More than 14.4	More than 10.1
Mean Wind Speed (Knots)	1st Quartile	1	Less than 6.7	Less than 6.5	Less than 7
	2nd Quartile	2	6.7 to 9.19	6.5 to 8.79	7 to 9.64
	3rd Quartile	3	9.2 to 12.3	8.8 to 11.9	9.65 to 12.7
	4th Quartile	4	More than 12.3	More than 11.9	More than 12.7

The results for the three regression models can be viewed in Table 3-5. The significance for all the variables were less than 0.05, with the exception of rainfall in the summer model which was only marginally over 0.05 with a value of 0.051. The R-squared for the three models was adequate, with the winter model having the best R-squared of 0.39. The data in the regression model is non-parametric and therefore an R-squared of above 0.5 would not be expected. The R-squareds in the models are more than adequate for this type of regression. The all year model contained the most data with 566 entries, followed by the summer model with 320, and then the winter model had 246.

The reference category for the dependent variable ("Usagecat") is category 4. When reading Table 3-5, the beta values (B) are referenced off when usage is high. For example, we can see if we look at temperature for the all year model, when everything else is held the same:

That when usage is low ("Usagecat"=1):

- Temperature will be 3.83 times more likely to be low ("Tempcat" = 1 or temperature less than 8.45^{o}C) than when usage is high.
- Temperature will be 4.13 times more likely to be low-medium ("Tempcat" = 2 or temperature between 8.45^{o}C and 10.99 ^{o}C) than when usage is high.
- Temperature will be 2.52 times more likely to be medium-high ("Tempcat" = 3 or temperature between 11^{o}C and 13.44 ^{o}C) than when usage is high.

To summarise the previous bullets, when all else is held the same, when temperature is low, then it is more likely that there will be fewer users than when the temperature is high. So using Table 3-5, we were able to determine the following about the different weather parameters for the different times of the year.

3.3.1 Rainfall

For the all weather model

The all weather model was not very conclusive for rainfall. This model predicts that when usage is low, that rainfall is 1.7 times more likely to be low than high and that when usage is high, it is 1.7 times more than rainfall is high rather than low. This is not very intuitive and anecdotal evidence would suggest otherwise. It was results like these (and the all year wind section) that resulted in the summer and winter models being considered. It was found that when the data was separated into seasons, more intuitive results were received, as can be seen in the following paragraphs. This issue is believed to arise due the presence of more commuters/local usage in the winter model than the summer model.

For the summer model

This model indicates that the users over the summer are much more sensitive to the rainfall than the other models. It can be seen that if Usage is low, then it is approximately 18 times less likely that rainfall is low than high. From this it can be deduced that when usage is high, it is 18 times more likely that rainfall is low than high.

For the winter model

This model indicates that when usage is low that it is 2.6 times less likely that rainfall is low than high. Similarly, we can say that when usage is high, it is 2.6 times more likely that rainfall is low than high.

3.3.2 Temperature

For the all weather model

This model indicates that users throughout the year are sensitive to temperature. When usage is low, it is approximately 4 times more likely that temperature is low and low-medium, than high. Similarly, when usage is high, it is approximately 4 times more likely that temperature is not low or low-medium.

For the summer model

The summer model agrees with the all year model except it is larger with the coefficients. When usage is low, it is approximately 20/21 times more likely that temperature is low and low-medium, than high. Similarly, when usage is high, it is approximately 20/21 times more likely that temperature is not low or low-medium.

For the winter model

The winter model also agrees with the previous two models. When usage is low, it is approx approximately 2 times more likely that temperature is low and low-medium, than high. Similarly, when usage is high, it is approximately 2 times more likely that temperature is not low or low-medium.

3.3.3 Wind

For the all weather model

Wind was found not to have an overly large affect on usage for the all weather model. It can be seen however, that when usage is low, that it is 0.062 time more likely that wind is low than high. This beta value is very small and for the entire all year model it can be seen that wind played a small part of the impact on usage.

For the summer model

Wind was found to have a greater role in the affect on usage for the summer model. It was found that when wind was low-medium or medium high, it was approximately 18 times more likely that usage was low than high.

For the winter model

Similar to the summer model it was found that when usage is low, it is 23 times for likely that wind is high rather than low. When usage is high, it is 23 times more likely that wind is low rather than high.

Table 3-5 Results of Multinomial logistic regression analysis performed on wind and temperature

All Year Model – Usage Data

Likelihood Ratio Tests			
Effects		Chi^2	Sig.
Intercept		.000	.000
Rain		29.487	.001
Temp		136.442	.000
Wind		19.105	.028
-2Log likelihood of Reduced Model			
Intercept		505.07	
Rain		534.55	
Temp		641.51	
Wind		524.17	
Parameter Estimates			
		B	Sig.
Usagecat=1	Intercept	-1.536	.005
	[RainCat=1]	1.701	.000
	[RainCat=2]	.976	.018
	[RainCat=3]	.003	.995
	[RainCat=4]	0	.
	[Tempcat=1]	3.826	.000
	[Tempcat=2]	4.127	.000
	[Tempcat=3]	2.523	.000
	[Tempcat=4]	0	.
	[Windcat=1]	.062	.879
	[Windcat=2]	.859	.070
	[Windcat=3]	-.091	.813
	[Windcat=4]	0	.
Usagecat=2	Intercept	-1.134	.011
	[RainCat=1]	1.680	.000
	[RainCat=2]	1.406	.001
	[RainCat=3]	.687	.085
	[RainCat=4]	0	.
	[Tempcat=1]	-.238	.573
	[Tempcat=2]	.725	.077
	[Tempcat=3]	.664	.064
	[Tempcat=4]	0	.
	[Windcat=1]	.668	.093
	[Windcat=2]	1.374	.003
	[Windcat=3]	.098	.801
	[Windcat=4]	0	.
Usagecat=3	Intercept	-1.042	.016
	[RainCat=1]	1.575	.000
	[RainCat=2]	1.233	.002
	[RainCat=3]	.547	.159
	[RainCat=4]	0	.
	[Tempcat=1]	.479	.221
	[Tempcat=2]	.864	.035
	[Tempcat=3]	.405	.272
	[Tempcat=4]	0	.
	[Windcat=1]	.301	.453
	[Windcat=2]	1.452	.001
	[Windcat=3]	.232	.540
	[Windcat=4]	0	.
The reference category is Usageca = 4			
	-2log-likelihood convergences		505.072
	N		566
	Nagelkerke R^2		.300

Summer Model – Usage Data

Likelihood Ratio Tests			
Effects		Chi^2	Sig.
Intercept		.000	.000
Rain		16.532	.051
Temp		26.018	.002
Wind		22.110	.009
-2Log likelihood of Reduced Model			
Intercept		237.037	
Rain		253.569	
Temp		263.055	
Wind		259.147	
Parameter Estimates			
		B	Sig.
Usagecat=1	Intercept	-1.966	.274
	[Raincat=1]	-17.916	.996
	[Raincat=2]	.086	.952
	[Raincat=3]	.770	.622
	[Raincat=4]	0	.
	[Tempcat=1]	21.463	.000
	[Tempcat=2]	20.337	.000
	[Tempcat=3]	2.791	.032
	[Tempcat=4]	0	.
	[Windcat=1]	-.551	.597
	[Windcat=2]	-17.882	.996
	[Windcat=3]	-18.877	.996
	[Windcat=4]	0	.
Usagecat=2	Intercept	2.476	.010
	[Raincat=1]	-1.043	.208
	[Raincat=2]	-1.102	.185
	[Raincat=3]	-.522	.561
	[Raincat=4]	0	.
	[Tempcat=1]	19.089	.000
	[Tempcat=2]	18.518	.000
	[Tempcat=3]	1.097	.029
	[Tempcat=4]	0	.
	[Windcat=1]	-.969	.169
	[Windcat=2]	.091	.912
	[Windcat=3]	-.669	.373
	[Windcat=4]	0	.
Usagecat=3	Intercept	1.178	.240
	[Raincat=1]	-.108	.901
	[Raincat=2]	-.277	.751
	[Raincat=3]	-.068	.942
	[Raincat=4]	0	.
	[Tempcat=1]	19.202	.
	[Tempcat=2]	18.687	.
	[Tempcat=3]	.906	.080
	[Tempcat=4]	0	.
	[Windcat=1]	-.779	.287
	[Windcat=2]	.620	.460
	[Windcat=3]	-.242	.754
	[Windcat=4]	0	.
The reference category is Usagecat = 4			
	-2log-likelihood convergences		237.037
	N		320
	Nagelkerke R^2		.216

Winter Model – Usage Data

Likelihood Ratio Tests			
Effects		Chi^2	Sig.
Intercept		.000	.000
Rain		48.857	.000
Temp		22.449	.008
Wind		30.683	.000
-2Log likelihood of Reduced Model			
Intercept		267.178	
Rain		316.035	
Temp		289.628	
Wind		297.861	
Parameter Estimates			
		B	Sig.
Usagecat=1	Intercept	.637	.410
	[Raincat=1]	-2.608	.037
	[Raincat=2]	-1.668	.047
	[Raincat=3]	-1.135	.088
	[Raincat=4]	0	.
	[Tempcat=1]	2.311	.006
	[Tempcat=2]	1.090	.177
	[Tempcat=3]	.801	.323
	[Tempcat=4]	0	.
	[Windcat=1]	-23.120	.
	[Windcat=2]	-.570	.419
	[Windcat=3]	-.041	.957
	[Windcat=4]	0	.
Usagecat=2	Intercept	-.105	.890
	[Raincat=1]	2.167	.005
	[Raincat=2]	1.214	.090
	[Raincat=3]	.161	.820
	[Raincat=4]	0	.
	[Tempcat=1]	-.175	.809
	[Tempcat=2]	-.046	.948
	[Tempcat=3]	.476	.472
	[Tempcat=4]	0	.
	[Windcat=1]	-.479	.495
	[Windcat=2]	-.643	.357
	[Windcat=3]	.166	.824
	[Windcat=4]	0	.
Usagecat=3	Intercept	.759	.255
	[Raincat=1]	1.300	.064
	[Raincat=2]	.809	.191
	[Raincat=3]	.420	.469
	[Raincat=4]	0	.
	[Tempcat=1]	-.288	.655
	[Tempcat=2]	.080	.897
	[Tempcat=3]	-.270	.658
	[Tempcat=4]	0	.
	[Windcat=1]	.060	.925
	[Windcat=2]	-.213	.734
	[Windcat=3]	.592	.385
	[Windcat=4]	0	.
The reference category is Usagecat = 4			
	-2log-likelihood convergences		267.178
	N		246
	Nagelkerke R^2		.390

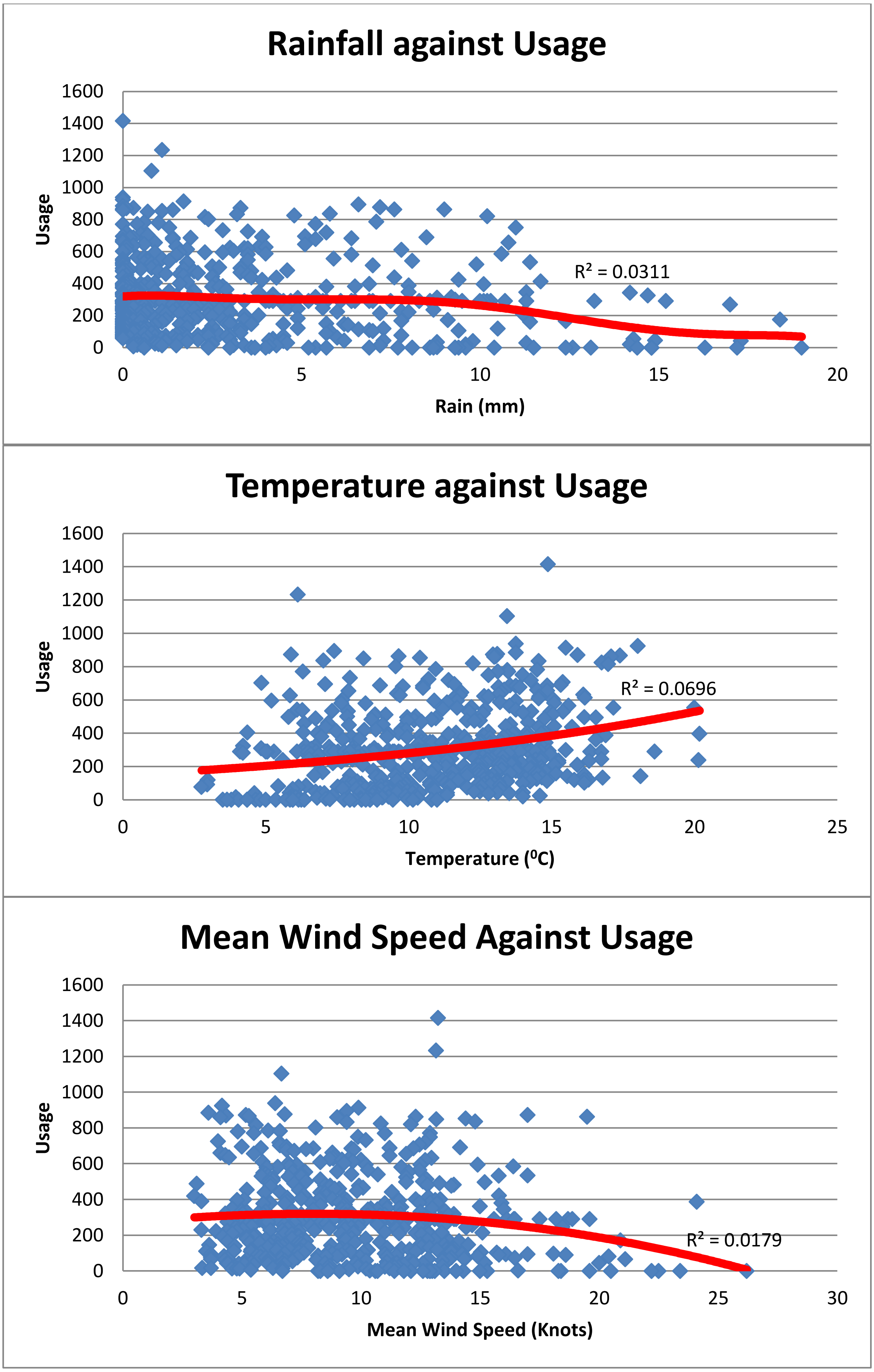

Figure 3-4 Graphs Containing Weather Data and Usage Numbers

3.3.4 Conclusion and Discussion from Case Study

Providing infrastructure similar to the Great Western Greenway throughout the country could prove to be important at reducing pollution, obesity and traffic congestion. The Greenway is located in a predominantly rural area and was expected to be mostly used by tourists. From analysis of the usage counters along the greenway, it can be seen that there are notable morning peaks and afternoon/evening peaks Monday to Friday, whereas at the weekends there is no peak in morning, however usage consistently increases as the day progresses. This indicates that not only are tourists using this facility, but it is being used as a sustainable travel mode by locals.

The usage and weather data indicate certain intuitive relationships. It can be seen from Figure 3-4 and Table 3-5 that for the summer and winter models that as rainfall increases usage decreases. As for temperature, the all year, summer and winter models all agree that as temperature increases, there is an increase in usage along the Great Western Greenway. Wind appears to be the least important weather parameter of the three in the model, but it still has an impact on the usage. It can be seen across the three models that there was a general reduction in the usage of the Great Western Greenway with the increase in mean wind speed.

From looking at the tourism expenditure, it can be estimated that domestic and non-domestic tourists spend for the local area is approximately €1,062,520 per year while visiting. From these figures alone, the facility has a payback period of 6 years. These figures indicate that investing in cycling facilities in areas that cater not just for local usage, but also for tourists can be very worthwhile to the local economy. The small local population of the area alone would not warrant an investment of €5.7 million in cycling facilities. However, the amount of tourists using the Greenway has made the facility a very worthwhile investment.

From this study, it became apparent that aside from the contributions from tourists to the local economy, there was no way of identifying how the facility was valued by the tourists. Would the same tourists have come to the area if the greenway didn't exist? Would they have visited if there were cycle lanes along the parallel national road? The question of how much extra value is derived from the segregated facility, over a road with a cycle lane or a road without cycling infrastructure cannot be addressed using present day evaluation methods. The study also demonstrated that there were a considerable number of recreational users; however, determining the value derived from facilities such as the Great Western Greenway by recreational users was not possible.

It was identified that a method that could assess the value derived from different standards of cycling facilities, by different categories of people would be a very useful tool. This would allow for a better evaluation of existing cycling infrastructure, and would allow for accurate appraisals of proposed cycling infrastructure.

3.4 Initial Scoping Survey

This section presents the results from an initial scoping survey that was undertaken in the spring of 2012. The purpose of this survey was to identify the attributes that were most pertinent for the stated preference study. When conducting a stated preference study, it is vital to reduce the complexity of the study. Therefore, it is important to select the most relevant attributes that effect cycling, and not include attributes that are superfluous.

3.4.1 Introduction

The determination of the key attributes to be included in the stated preference study needed to be identified. It was determined that the best method for achieving this was by means of a scoping survey. The purpose of the stated preference survey was to determine how tourists, commuters, and recreational cyclists perceive varying standards of cycling infrastructure. Whether these categories would be willing to sacrifice time, comfort and energy, in order to travel upon perceived safer cycling infrastructure needed to be identified. There are models that have been used to evaluate similar questions for cycling for commuting purposes (Caulfield et al (2012), Stinson and Bhat (2004), Stinson and Bhat (2003)). However, to the best of the author’s knowledge, no research has been carried out into a model to access cycling for touristic and leisure purposes.

3.4.2 Methodology

It was fundamental to determine the key attributes that could be used in the stated preference evaluation. These attributes were identified from studies completed around the world, and were compiled into a list of the ten most relevant attributes (Stinson and Bhat (2003), Caulfield et al (2012), Morris (2004), Downward et al (2009)), which are as follows:

- Vehicle Parking.
- Route Slope.
- Comfort.
- Ancillary Facilities.
- Time.
- Cost.
- Weather.
- Type of Facility.
- Directness.
- Route Length.

It was decided to compile a scoping survey that consisted of all of these attributes. In the scoping survey, respondents were asked to rank five out of the ten attributes in order of importance, that they considered in the decision process to cycle or not for a work/educational related trip, and to repeat this process again for a recreational trip. The results of the rankings can be seen in Table 3-6. This scoping survey was undertaken in the spring of 2012 and received over 500 responses. The respondents were presented with the ten attributes, and were asked to rank five of the following ten attributes in order of importance to them, in the decision process to cycle or not for; firstly a work/education related trip and secondly for a recreational related trip. They were asked to rank the reasons in order of importance with 1 being the most important and 5 being the least important of the selected reasons.

3.4.3 Analysis

The results for the work related trip indicated that “Time” was awarded the most 1s in the ranking order, with “Vehicle Parking” being awarded the least 1s. “Comfort” was awarded the most 5s in the rankings, with “Type of Facility” being awarded the least. The results from the recreational related trip indicated that “Weather” was awarded the most 1s in the ranking, with “Directness” being awarded the least. “Comfort” was awarded the most 5s in the rankings, with “Route Slope” being awarded the least. The scorings from the rankings were then weighted, with a ranking of 1, having a weight of 5, and a ranking of 5 having a weighting of 1. These weightings were then summed for each attribute, and divided by the number of people that ranked that attribute. This calculated the weighted average for each attribute. So the higher the score an attribute received, the higher it was ranked by the respondents. The weighted average for these attributes can be seen in Table 3-6. It can be seen that for the work related trip, “Time” scored the highest, with a weighted average of 3.81. For the work related trip, “Directness” scored the lowest with a weighted average of 2.43. For the recreational trip, “Weather” scored the highest with a weighted average of 3.68. “Directness” scored the lowest with a weighted average of 2.12.

Table 3-6 Weighted Averages of Attributes for Both a Work Related Trip and a Recreational Trip

Weighted Average for a Work Related Trip	
Time	3.81
Cost	2.99
Type of facility	3.02
Weather	3.26
Route length	3.50
Route slope	2.72
Ancillary facilities	2.82
Vehicle parking	2.50
Directness	2.43
Comfort	2.44

Weighted Average for a Recreational Trip	
Time	3.19
Cost	2.86
Type of facility	3.55
Weather	3.68
Route Length	3.19
Route Slope	2.80
Ancillary Facilities	2.75
Vehicle parking	2.57
Directness	2.12
Comfort	2.68

It can be observed in Table 3-6, that “Time”, “Route Length”, “Weather”, “Type of Facility” and “Cost” are the top five attributes for a work/education related trip, and that for a recreational trip that the top five attributes are “Weather”, “Type of Facility”, “Route Length”, “Time”, and “Cost”. From Table 3-6, it could be seen that the top five attributes for both work and recreational related trips were the same, except for the ordering. It was decided to omit “Cost” and “Route length”. “Cost” and “Route Length” were omitted from the scenarios as “Cost”, “Time” and “Route Length” would be highly correlated. This is because these attributes are intrinsically connected. For example, as the route length increases so too does the time and cost. It was decided that "Time" would be used, as it can act as a proxy for both "Route Length" and "Cost". Therefore, it was decided to include "Route Slope" and bring the number of attributes for further investigation to four. "Route Slope" was included, as this variable would be more relevant than "Ancillary Facilities" for the study area, since some parts of the study area have moderate to severe gradients. Ergo, the four attributes progressed for the stated preference study are as follows:

- Type of facility.
- Time.
- Weather.
- Route Slope.

3.4.4 Conclusions

This piece of exploratory research demonstrated that attributes of a trip vary depending on trip purpose. This analysis allowed the most important attributes to be determined from the rankings from a scoping survey. The conclusions from this study are as follows:

1. For a work related trip, the top five attributes in order of importance are time, route length, weather, type of facility and cost.
2. For a recreational trip, the top five attributes in order of importance are weather, type of facility, route length, time and cost.
3. Time, route length and cost are highly correlated, but time can act as a proxy for both route length and cost.
4. Route slope was included for further investigation instead of route length and cost.
5. Attributes used for the stated preference survey: time, weather, route slope and facility type.

3.5 Summary

The case study allowed for a section of exploratory research to be conducted into cycling infrastructure, in Ireland. From the analysis, it can be estimated that domestic and non-domestic tourists spend approximately €1,062,520 per year, in the local area while visiting. From these figures alone, the facility has a payback period of 5 years. These figures indicate that investing in cycling facilities in areas that cater not just for local usage, but also for tourists can be very worthwhile to the local economy. The small local population of the area alone would not warrant an investment of €5.7 million in cycling facilities. However, the amount of tourists and recreational users utilising this piece of infrastructure has made the facility a very worthwhile investment.

From this case study there was no way of identifying how the facility was valued by the tourists and recreational users. The question of how much extra value is derived from the segregated facility, over a road with a cycle lane or a road without cycling infrastructure cannot be addressed. Determining the value derived from facilities such as the Great Western Greenway by recreational users was not possible. It was identified that a method that could assess the value derived from different standards of cycling facilities, by different categories of people would be a very useful tool. This would allow for a better evaluation of existing cycling infrastructure, and accurate appraisals of proposed cycling infrastructure.

From the results of the scoping survey, it was identified that: time, cost, weather, route length and facility type were ranked in the top five for both work related trips and recreational trips, with the order of importance differing. Route length and cost were omitted due to correlation with time. However, time can act as a proxy for route length and cost. Route slope was included in place of route length and cost. Therefore, the four attributes progressed for the stated preference survey are:

- Facility Type.
- Time.
- Weather.
- Route Slope.

The case study and the scoping survey allowed for analysis of usage of cycling infrastructure to progress, by firstly identifying the gaps in the present methods of analysis and then development of aspects most relevant to cycling infrastructure. This allowed for an effective stated preference survey to be achieved by keeping it as relevant to the respondents as possible. By including the most relevant attributes to cycling in the following stated preference analysis, the models were kept as simple as possible by not including any unnecessary variable.

4 Methodology

4.1 Introduction

This chapter presents the methodologies followed to construct two versions of a stated preference survey, to analyse the subsequent data collected, and outlines the process utilised for carrying out the health economic analysis. The methodologies used for the Chapter 3, are contained within that chapter. This chapter is solely concerned with the process that was used for the analysis in Chapter 6 and Chapter 7. The first section of this chapter details the stated preference scenarios examined, the attributes and attribute levels, and the fractional factorial design applied. The second section presents the steps completed to construct the survey including the layout of the survey and the purpose behind the questions asked. The following section outlines the sampling method used to obtain the respondents for this survey. The theories of discrete choice modelling and the theories that are pertinent to this thesis are then highlighted in the subsequent section. The following section details the estimation procedures used to produce the models presented in Chapter 6.

The behavioural outputs from the discrete choice models and the interpretation of these outputs are then described (Discrete choice is the name given to the analysis of stated preference results). The procedure used to calculate the willingness to pay of individuals from the estimated model coefficients is then defined. Finally, the system required for calculating the health benefits from the stated preference survey and the description of the tool used is presented. This chapter concludes with a summary section.

As identified in the Chapter 2, the stated preference survey approach is the most appropriate method of investigating the construction of proposed cycling infrastructure. The various other methods of evaluating cycling infrastructure are not suitable for the appraisal of a proposed cycle route. The stated preference method is widely used and the methods of implementing this approach are well documented.

4.2 Survey Design

The survey targets two separate groups of people, namely tourist and the study area population. This required two versions of the survey. The tourist version seeks information for tourist related trips, whereas the study area survey seeks information for commute and recreational related trips. This section outlines the design procedure undertaken to produce the two versions of the survey. The general survey structure that formed the skeleton of the two versions of the survey contained three sections, which are as follows:

1. Cycling and the Perception of Cycling.
2. Scenarios.
3. Personal Demographic Information.

The scenarios section contained several stated preference scenarios. These scenarios present the respondent to the survey with a hypothetical situation where there are several options. Each option has varying condition and the respondent can only select one option. Therefore, it was important that the design of the scenarios delivered ample information to the respondents to allow them to make informed choices. The scenarios presented in the survey are outlined, as are the attributes and attribute levels, and the fractional factorial design process. It was also important to keep the survey concise to ensure respondent fatigue was avoided.

4.2.1 Stated Preference Scenarios Examined

The scenarios section was similar for the two versions of the survey. In the scenarios section of the tourist version of the survey, respondents were asked to consider four scenarios in the context of a tourist related trip. The study area version of the survey also contained four scenarios, but the respondents to this survey were asked to consider the scenario, firstly for a commute trip, and make a choice, and then for a recreational trip, and make a choice. The four scenarios presented to the respondents of both versions of the survey were in the context of a trip in a rural and interurban context, with the mode of transport being the bicycle. The four scenarios presented were similar but contained varying conditions relating to the available infrastructure in each scenario.

4.2.2 Attribute Levels

In stated preference studies, individuals are asked to choose between several alternatives which vary depending upon the attribute level attached. An alternative in this study refers to the type of cycle infrastructure options (road without any cycling infrastructure, road with cycle lanes, and a cycling facility which is fully segregated from traffic). The attributes of these alternatives are the identifying factors which define these alternatives. For this study, the attributes are cycle travel time, weather and route gradient. Please see Section 3.4 of Chapter 3 for more information on why these attributes were selected for the stated preference study. The attributes for this study were chosen from:

1. Literature Review.
2. Judgement.
3. Scoping Survey.

In order for the individuals to choose between the options presented in this study, it was necessary to place a travel time on the different types of cycling infrastructure. As this is a stated preference study, the majority of the options presented are currently not available, it was therefore necessary to place a value on this option using similar options already available. This section presents the attributes and the attribute levels.

Time – Attribute Levels

It was decided to present three generalised levels of travel time taken: 10 minutes, 20 minutes and 40 minutes. The purpose of these levels is to ascertain how much time respondents would be willing to sacrifice in return for high quality cycling facilities. The same attribute levels are used for all the alternatives examined, road without cycling infrastructure, road with cycle lane, and fully segregated from traffic cycle facility.

These generalised times were selected for several reasons. As mentioned in the introduction chapter, this study is being completed with a study area in mind. The travel time to cycle between the urban centres located along the proposed cycle route vary between 10 minutes and 40 minutes. The potential options for usage of the route also vary from the most direct route to routes that require substantial deviation from the shortest route.

It was also important to look at other stated preference studies completed and the times that were used. Tilahun et al (2007) completed a stated preference survey in St Paul in

Minnesota. The times used in this survey varied between 20 minutes, 40 minutes and 50 minutes. Caulfield et al (2012) looked at cyclists' preferences for different standards of cycling infrastructure in Dublin by means of a stated preference survey. The times used in this study varied between 10 minutes, 20 minutes and 30 minutes. Hopkinson and Wardman (1996) in a study of cyclists and safety conducted a stated preference survey in Bradford in the United Kingdom. This stated preference survey used times of 10 minutes, 15 minutes and 25 minutes in the stated preference survey.

From the literature review, and in the context of the study area, it was decided that the times of 10 minutes, 20 minutes, and 40 minutes are appropriate for the type analysis performed in this thesis.

Weather – Attribute Levels

It was decided to use three attribute levels for weather: dry, windy, and, wet and windy. These three attribute levels were chosen as they represented the most common weather patterns experienced in Ireland.

The purpose of this attribute was to establish how weather affects the decision in choosing different standards of cycling facility. This variable can be used as a form of proxy for discomfort, as it is assumed that most people would want to avoid inclement weather, so persevering through inclement weather to cycle upon a better quality cycling facility would demonstrate a willingness by individuals to trade comfort for a perception of safety.

It was important that the weather parameters analysed in this study be relevant to the context of the study area. Other weather parameters analysed in similar studies ranged from excessive heat to excessive cold and the occurrence of snow (Nkurunziza et al (2012); Bergstrom and Magnusson (2003); Noland and Kunreuther (1995)). In the environment of the study area, the weather is temperate where extreme highs and lows are either rare or have never occurred, and noteworthy snowfall is rather sporadic. For the temperate climate in the study area, dry, windy and wet weather is common and therefore most relevant to this study.

Route Gradient – Attributes

It was decided to present three levels of route gradient: flat, moderate and steep. The purpose of these levels was to investigate how respondents value cycling facilities with a more level topography, and how increases in gradients affect the choice between the alternatives. The same route gradient attributes are used for all the alternatives analysed. From looking at similar stated preference studies that analyse route gradient, it can be seen that these three attribute levels categorise and encompass most of the possible gradients that are experienced, whilst maintaining a simply designed stated preference survey.

The attributes and the attribute levels can be observed in Table 4-1.

Table 4-1 Attribute Levels in the Scenarios

	Attribute Levels		
Attribute	**Road without facilities**	**Road with Cycle Lanes**	**Cycling facility Segregated from Traffic**
Time	10 minutes	10 minutes	10 minutes
	20 minutes	20 minutes	20 minutes
	40 minutes	40 minutes	40 minutes
Weather	Dry	Dry	Dry
	Windy	Windy	Windy
	Wet and Windy	Wet and Windy	Wet and Windy
Route Gradient	Flat	Flat	Flat
	Moderate	Moderate	Moderate
	Steep	Steep	Steep

4.2.3 Factorial Design

In this study, the scenarios contain three alternatives. These alternatives are characterised by the attributes. The attributes for this study were travel time, weather and route gradient. The attributes and the attribute levels vary over the alternatives for each of the four scenarios. A single combination of these alternatives, varied by their attributes and attribute levels are called a treatment combination. A full factorial design is where all possible combinations of the alternatives, attributes and attribute levels are enumerated (Hensher et al, 2005).

Each of the attributes in this study has three levels. Table 4-1 displays the attributes and their attribute levels. In this study there are three alternatives and nine attribute levels (three travel time levels, three weather levels, and three route gradient levels). If a full factorial were to be used of 3^9, there would be 19,683 treatment combinations to be evaluated. As one might expect, testing this many treatment combinations would not be practical. From Bateman et al (2002), it is known that as the numbers of attributes and attribute levels increase, the possible combinations of these increase exponentially. Therefore, using a full factorial design becomes extremely difficult when complex studies are undertaken.

4.2.4 Fractional Factorial Design

Full factorial designs are only practical in situations where the stated preference study contains a small number of attributes with very low attribute levels (Louviere et al, 2000). Fractional factorial designs are a more practical way of conducting stated preference analysis where the number of attributes and attribute levels are higher. A fractional factorial design selects a representative sample of treatment combinations from the full factorial design. This sample allows for the effects of the variables to be estimated in an efficient manner. This sample is not randomly selected from the full factorial. The process of selecting the sample is carried out using several statistical methods that have been developed to produce fractional factorial designs. This sample allows for the best combination of values to be estimated for the coefficients.

A fractional factorial design allows for a stated preference study to be undertaken in a practical manner. The approach used in this thesis was an orthogonal main effects fractional factorial design. This method is based on the assumption that each attribute is independent and does not have an effect or interaction on any of the other attributes in the study. Main effects typically account for 70% to 90% of the explained variance, whereas interaction effects usually explain 5% to 15% of the variance. Therefore, by using a main effects model, the majority of the variance can be accounted (Hensher et al, 2005). If it was desired to observe two or three way interaction effects or more, a much larger design would be required involving an increase in the number of treatment combinations. This would increase the complexity and most likely have a detrimental effect on the final model. IBM's SPSS software package was used to create the fractional factorial design. The method for producing this design using this software was taken from Hensher et al (2005). It is important to note that orthogonality is a mathematical constraint requiring that all attributes be statistically independent of one another. Orthogonality implies that there is zero correlation between attributes.

4.2.5 Survey Versions

Bradley and Daley (1994) demonstrate that there is an increase in error as a respondent moves from one stated preference experiment to the next. This effect is related to respondent fatigue and is an issue that is of very high importance when designing a survey. Adamowicz et al (1998) found that in stated preference study containing eight choice sets, and within these choice sets there were three alternatives, there was no increase in error from one choice experiment to the next. However, Phillips et al (2002) found an increase in error when there were twelve choice sets. The first group of six choice sets had a lower error, with the second group of six recording an increase in error. Holmes and Boyle (2005) found that in an experiment with four choice sets, there was an increase in error between the first choice set and the fourth choice set. Caussade et al (2005) found that after nine choice tasks were undertaken by respondents, fatigue effects started to appear. Rafaelli et al (2009) found when respondents were presented with sixteen choice sets, after the tenth choice set, the error started to increase. From reviewing the available literature, it can be seen that there appears to be an area of between the eighth and tenth choice set where fatigue effects start to cause errors in experiments. From this, it was decided that the maximum amount of choice sets that the respondents to the study area survey should encounter is eight. In order for respondents to achieve this in the fractional factorial design, a blocking variable is required. A blocking variable is an extra variable included in the fractional factorial design that allows the scenarios from the fractional factorial design to be grouped according to how many levels you have allowed for in the blocking variable.

Blocking variables are included in the estimation of the fractional orthogonal design in order to reduce the number of choice sets each respondent to the survey would have to complete. This blocking variable allowed the treatment combinations to be segmented and the treatment combinations within the groups to be selected in a statistically significant manner. The blocking variable is treated as another attribute in the estimation process. For the design in this study, the blocking variable had eight attribute levels. Each block is given to a different respondent

The fractional factorial design produced by SPSS required 32 treatment combinations to be examined in this study. Using the blocking variable as a reference, these treatment combinations were blocked in to eight groups of four.

4.3 Survey Layout

This section outlines the layout of both versions of the surveys used in this study. Copies of both surveys can be viewed in Appendix 2 and Appendix 3. It can be seen in the subsequent sections how the two versions of the survey were similar in nature, but catered for two different target respondents.

4.3.1 Introductory Page

Both versions of the surveys contained an introductory section. A welcome note contained a quick synopsis of the reason the survey was being conducted. Van Horn et al (2009) reviewed 308 different stated preference surveys that spanned over twenty years. Van Horn et al (2009) found that the use of incentives is generally innocuous. Patrick et al (2013) used two different incentive methods in order to encourage responses to a survey among students in a university. A $10 pre-incentive only, and a $2 pre-incentive and a promised $10 post incentive were found not to have an effect on the response rate. Even though the pre and the post incentive structure did not have an effect on the response rate, the pre and post incentive method was found to be more cost efficient. This method also found that more people completed the survey. Therefore, the pre and the post incentive would be the better method for an incentive. Boser & Clark (1996), Fox et al (1988), Greer et al (2000), Jobber & O'Reilly (1998), Watson & Woodliff (2003), all found that incentives have been unambiguously found to increase the response rates of surveys. After reviewing this literature, it was decided to offer the respondents to the study area survey an incentive to complete the survey. The incentive would be a post-incentive, in the form of entry into a raffle for a shopping voucher.

The tourist surveys did not contain an incentive. The incentive used to attract respondents to the survey was entry into a raffle for a shopping voucher of a certain value (valid in most shops in Ireland). As most tourists would have departed the country when the draw for the prize would take place, it was decided it was not suitable to include the tourists in this incentive. The introduction to the tourist surveys highlighted that the survey was short, and would not take up much of their time. These tourist surveys were also carried out by means of an intercept, and the shortness of the survey was also highlighted verbally by the distributor. The study area survey introduction also outlined the layout, and emphasised that only those who completed the survey would be entered into the raffle for the shopping voucher.

4.3.2 Section 1 – Respondent's Perceptions and attitudes of cycling

Following the introduction to the survey, the first collection of questions for the survey commenced. The collection of questions differed depending on the target group.

Section 1 – Tourist Survey

The tourist survey began by asking the respondent to state what their purpose was in visiting Ireland. The length of their stay was then sought. The respondents were asked if they had, or if they planned on cycling whilst they were visiting Ireland, and if so, how they obtained or planned to obtain the bike. Subsequently, they were questioned on whether this was their first time visiting Ireland, and if they would recommend visiting Ireland from their experience of holidaying in the country. The respondents were then asked to rate the cycling facilities in Ireland, either from direct experience or from observation, and if improvements were made would it encourage them to visit again. The respondents were asked to characterise the experience of cycling in Ireland (again either from direct experience or observed), and if they would use a high quality cycling facility with access to tourist attraction if it was near to where they were staying. The respondents were then asked would the proximity of potential accommodation to a high quality cycling facility encourage them to stay in accommodation over accommodation that was not similarly situated. See Appendix 2 for a copy of the survey.

Section 1 – Study Area Survey

In the first section of the study area survey, it began by questioning the respondent's daily commute. For those that did cycle, the reasoning behind them choosing to cycle was asked, and similarly, for those that did not cycle, the reasoning behind them not choosing to cycle was also sought. Following this, the respondents were then questioned on their experiences of cycling and cyclists. If the respondents cycled, they were questioned on the regularity and for how long they have been cycling. Information on their commute (time/distance) and their confidence as a cyclist was next. Subsequent to this, whether or not the respondents cycled for recreational purposes was questioned. The reasoning behind whether or not they cycled was queried for a recreational trip. The section following this contained generic questions on cycling in Ireland, such as how they would rate the cycling facilities in their area, have they cycled in the past year for various reasons, etc. Please see Appendix 3 for a copy of this survey.

Questions for the HEAT analysis

Within Section 1 of the study area survey, the questions pertaining to the health economic assessment were posed. See Section 4.9 for more information on this assessment. Here, the respondent was presented with an image of a high quality cycling facility. The cycling facility is fully separated from traffic, and of a very high standard. The respondent was asked whether or not they would use a similar facility if it was built along the proposed cycle route. They were firstly asked if they would utilise the piece of infrastructure to commute to and from their places of work and education, and then if they would use it for recreational purposes. They were then asked how regularly they would use it for commuting.

4.3.3 Section 2 – Scenario Evaluation

This section of the surveys consisted of the stated preference scenarios. This section began with the information on the options to be evaluated. The tourists were asked to evaluate the options in the context of a tourist related trip in the countryside, where the respondent would be travelling between two urban locations. The study area respondents were asked first to evaluate the scenarios in the context of a commute to and from their places of work and education. The study area respondent was then asked to re-evaluate their choice for the scenario in the context of a recreational trip in the countryside where they are travelling between two urban locations. In these scenarios the respondent was presented with different standards of cycling infrastructure that contained individual conditions for each piece of infrastructure. The respondent then selected their preferred option. A sample of a scenario presented to the respondents can be viewed in Figure 4-1. The three options presented with the varying travel time, weather and gradient conditions can observed in Figure 4-1.

Option A – Road with no cycling facilities	**Option B** – Road with cycle lanes	**Option C** – Fully segregated facility
		
The time on this facility is **10** minutes	The time on this facility is **40** minutes	The time on this facility is **10** minutes
The weather is **windy**	The weather is **dry**	The weather is **dry**
The gradients along this facility are **moderate**	The gradients along this facility are **flat**	The gradients along this facility are **flat**

Figure 4-1 Sample Scenario Presented to the Respondents

4.3.4 Section 3 – Socioeconomic Characteristics

The final section of the survey asked the respondents to fill in their personal details, such as age, gender, income, employment etc. The survey concluded by asking the respondents if they would like to be included in the raffle, and they were provided an optional comments box, where respondents could voice anything that they felt would be relevant to the survey.

4.4 Sampling Method

This section outlines the data collection techniques used in this study. The sampling frame, the method behind the intercepts, and the use of the internet as a surveying tool are discussed.

4.4.1 Defining the sample frame

As identified in Chapter 2, there are three distinct user groups that rural cycling infrastructure would cater for; tourists, commuters, and recreational users. The commuters and recreational users that needed to be targeted could be combined into one target group in the study area survey. It was decided to complete the survey within the University of Ireland, Maynooth, the Intel Ireland complex, the Hewlett Packard Complex and the Kilcock Business Association. These clusters of individuals were chosen for a number of reasons. Individuals within these organisations travel from many areas within and outside the study area. The individuals within these clusters could potentially utilise the planned cycle route within the study area and therefore, a sample of these individuals would prove to be a good cross section of the population within the study area. The University containing students and staff, along with the workforces in the other organisations allowed for a diverse mix of responses to be retrieved. A web-based surveying tool was chosen due to the speed and low-cost associated with collecting responses from this method. This method was also chosen as it proved the best method of accessing this population within the organisation. Most, if not all of the staff and students within these organisations have email addresses associated with the organisations that can be accessed easily. However, very few of the individuals would have separate postal addresses associated with the organisations. Therefore a postal survey, would not only be very costly, but also impractical.

The tourists were a distinct group separate to the other two groups. Accessing this group using an internet based survey proved very difficult as accessing these groups via the internet would be either through private tour companies or government bodies. The private touring companies and the government bodies were both unwilling to participate in the survey. Also, due to Data Protection Acts of 1988 and 2003 (Data Protection Commissioner, 2003) this information cannot be passed onto the public. It was determined that an intercept survey would be the easiest and most reliable method of accessing tourists.

4.4.2 Benefits of Intercept Surveys

Collecting the tourist information by means of an intercept had several advantages over the other methods of surveying. Van Horn (2008) found that surveys conducted via the internet may sometimes have a lower response rate than other methods. An intercept survey has many benefits as the surveyor will be there in person to assist the respondent. The surveyor can explain to respondents what is outlined in the survey, and be of assistance to anyone that has difficulty. This allows the surveyor to have a direct experience of the issues that may arise in the survey. It has been found that the use of intercepts improve most surveys. However, this method of surveying can be labour intensive, and are not completed on a large scale (Dillman, 2000). This method of surveying also allows for a reduction in bias, as the respondents do not need access or confidence in using the internet. An important aspect of the design of the tourist survey was that it was relatively short and concise. This was emphasised by the distributor to potential respondents.

4.4.3 Use of the internet as a survey tool

By using the internet, it was possible to create a more detailed survey, with skip patterns and logic conditions. Van Horn (2008) found that web based surveys generally have more ease of administration, faster collection of responses, lower costs, response confidentiality and data management when compared to postal administered surveys. However, there may be sample bias as the respondents must have access and confidence in using the internet. Dillman (2000) theorised that the development of surveying by means of the internet would have a profound effect on this area. However, surveying by means of the internet requires a somewhat different approach to the social exchange elements of responding to a survey. It is important that explaining how to respond correctly to internet based questions is completed accurately and effectively. The issue of security and data confidentiality associated with electronic technologies also raise the issue of trust. Internet based surveys have a more refined appearance and provide capabilities far beyond the capabilities of mail based surveys, such as randomisation of questions and pop up instructions should the respondent require them. With access to a large proportion of the population within the study area by means of the internet, along with the added benefits of completing the survey by means of the internet, it was concluded that this method of surveying the study population would prove very advantageous for the study in this thesis.

4.4.4 Sampling strategy used

The populations defined for this study was the population of the study area, and the tourist population in Ireland (total number of tourists that visit Ireland annually). The tourist and the study area surveys were carried out at different locations and at different times of the year.

The tourist season for Ireland peaks in the summer months and it was therefore decided to carry out the intercept survey for the tourists at this time, so as to maximise the tourist catchment. For the study area survey, it was decided to carry out the survey in the winter months, because firstly, most of the students would be in situ at the University of Ireland, Maynooth during term time. Secondly, many of the workforces in the study area would take holidays in the spring/summer months and therefore, there would be less people present to undertake the survey. By undertaking the survey in the winter months allows for the maximum amount of people to receive the survey.

The tourist intercepts occurred at two locations in Dublin City, Ireland. The first location was adjacent to the Trinity Walking Tours Kiosk in TCD. The second location was adjacent to an adventure tour company kiosk in a hostel in Dublin city centre. Dublin City was a very suitable location for these intercept surveys as the city contains six out of the ten most popular fee paying visitor attractions and nine out of the ten most popular free tourist attractions in Ireland (Fáilte Ireland, 2012). TCD is currently also in the top five tourist attractions in the country and the hostel was opposite another of the top tourist attractions (Dublin Castle) in the country (Fáilte Ireland, 2012). These two locations allowed for a large representative sample of tourists to be retrieved from the intercept surveys as it allowed access to a large range of tourists that are attracted to these locations. The survey was also translated into German, French and Spanish. In total there were 287 valid responses to the survey.

4.4.5 Defining the sample size

When defining the sample size, it is important to take the following considerations into account:

- The amount of sampling error that can be accepted.
- The population size.
- How varied the population is with regard to the characteristic of interest.
- The desired size of the confidence interval.

The sample size can be determined by using Equation 4-1 (Dillman, 2000):

Equation 4-1

$$Ns = \frac{(Npp)(pp)(1-pp)}{(Npp-1)\left(\frac{B}{C}\right)^2 + (pp)(1-pp)}$$

Where: Ns = Sample size required for the desired level of precision

- Npp = Size of Population.
  - pp = Proportion of the population expected to choose one of the two response categories.
  - B = Acceptable amount of sample error.

- C = Z statistic associated with the response level.

The expected variation in answers to a question of interest is accounted for in the expression *(pp)(1-pp)* in Equation 4-1. For example, in a question with two possible answers, this expression measures how much the study population of interest is varied in answering the question. In order to allow for maximum variation in the sample, a 50/50 split was used, therefore there is a 50% chance that a respondent would choose an option, and a 50% chance that they would not choose the option.

The two versions of the survey in this study would require two different sample size estimates. The required tourist sample size would be determined from the quantity of tourists that visit Ireland annually. This sample size would then allow a broad representation of the tourists that visit Ireland to be formed. The sample size for the study area would be calculated from the resident population of Ireland. The sample size calculated would allow for a broad representation of the population to then be formed.

For the tourist survey sample size, it is known that Ireland had 6.6 million visits by overseas residents in 2012 (Central Statistics Office, 2013). It was decided that a 5% margin for error and a 90% confidence level would suffice for this sample. Using these parameters, the following sample size was calculated for the tourist survey.

$$Ns = \frac{(6{,}600{,}000)(0.5)(1-0.5)}{(6{,}600{,}000-1)(\frac{0.05}{1.65})^2 + (0.5)(0.5)} = 271$$

With 287 valid responses, and a 90% confidence level, the margin for error is 4.9%. From the literature review, it was seen that the sample sizes for similar stated preference surveys internationally varied from 88 to 1,872 responses. As was seen in Chapter 2, an extensive review of stated preference surveys was undertaken. Stated preference surveys relating to cycling, and to tourism were examined. The responses rates to these surveys were noted and can be viewed in Table 4-2. From Table 4-2, it was decided a response level of approximately 300 was deemed to be sufficient in estimating results and conclusions.

Table 4-2 Stated Preference Surveys and Response Rates

Stated Preference and cycling	Responses
Sener et al (2010)	1,621
Tilahun (2007)	161
Wardman et al (2007)	969
Hopkinson (1996)	115
Stated Preference and Tourism	
Hough and Hassanien (2010)	88
Becken and Gnoth (2004)	1,122
Kozak (2001)	1,872
Zhang et al (2012)	761
Reilly et al (2010)	467

It is known that the study area in 2011 had a population of 141,777 (Central Statistics Office, 2012). It was deemed that a 5% margin for error and a 99% confidence level would be suffice for this sample. Using these parameters, the following sample size would was calculated for the study area survey.

$$Ns = \frac{(141{,}777)(0.5)(1-0.5)}{(141{,}777-1)(\frac{0.05}{2.58})^2 + (0.5)(0.5)} = 662$$

With 845 valid responses, and a 99% confidence level, the margin for error is 3.35%. A response level of approximately 385 (sample size with a confidence level of 95%) was deemed to be sufficient in estimating the results and conclusions, therefore the 845 valid responses was more than adequate for estimating the results from the scenarios for recreational and commute usage.

4.4.6 Data collection

In the winter of 2012/13, emails containing a link to the Internet based surveys were distributed to the National University of Ireland, Maynooth, the complexes at Intel and Hewlett Packard, and the Kilcock Business Association. The four groups were chosen as they were all within 1km of the proposed cycle route between Dublin and Mullingar. The National University of Ireland in Maynooth has over 8,500 students and over 400 staff members (National University of Ireland, Maynooth, 2013). Over two months, there were in total 661 valid responses. The Intel Ireland campus in Leixlip employs over 5,000 people (Intel Ireland, 2009). Over two months there were in total 57 valid responses. The Hewlett

Packard campus in Leixlip employs over 4,500 people (Business and Finance, 2013). Over two months there were in total 46 valid responses. The Kilcock Business Association is located in the town of Kilcock and has over 50 businesses as members. In early December 2012 an email was distributed to the businesses and was further distributed to the employees of the businesses. Over two months there were in total 81 valid responses. In total there were 845 valid responses to the survey. It is estimated that approximately 10,000 people received an email with the link to the survey. This would indicate that there was an approximate response rate of 9%.

The respondents to the study area survey answered the scenarios in the context of both recreational trips and commute trips, therefore the study area survey responses allowed for the creation of two different datasets; a commute dataset and a recreational dataset. By splitting the commute and recreational responses into separate datasets allowed for analysis to be performed on the results depending on trip purposes.

Stated preference surveys use the concept of pseudo respondents when constructing the database for respondents. This translates to every choice that a respondent makes is treated as an individual respondent. This would mean that if one respondent answered four choice sets, the database understands that this is four respondents making one choice each. Therefore, for the:

- Tourist dataset, there were 1,148 pseudo respondents (287 respondents x 4 choices).
- Commute dataset, there were 3,380 pseudo responses (845 respondents x 4 choices).
- Recreational dataset, there were 3,380 pseudo responses (845 respondents x 4 choices).
- The full dataset, there were 7,908 pseudo responses (1,148 + 3,380 + 3,380).

4.5 Discrete Choice Modelling

Discrete choice modelling is the term used to describe how stated preference data is examined. This section outlines the theory behind discrete choice modelling. The theory underpinning random utility theory, and multinomial logit models are described. For more detail on any aspect of these theories see Louvierre et al (2000), Hensher et al (2005), and Ben-Akiva & Lerman (1985).

4.5.1 Random utility theory

Discrete choice models are formed on the assumption that individuals make choices rationally and that they want to maximise their utility. The concept of random utility theory assumes that an individual will derive utility from alternative *j*. The utility that an individual derives from alternative *j* is U_{nj}, *j =1,...,J.* From Equation 4-2, an individual will only choose alternative *i* only if the utility derived from *i* is greater than the utility derived from other alternatives in the choice sets. Essentially this is assuming that the individual is rational.

Equation 4-2

$$U_{in} > U_{ij} \forall j \neq i$$

For random utility, it is assumed that the utility U_{ij} provided to individual *i* by product *j* is composed of a deterministic component V_i and a stochastic error component ε_i. The deterministic component V_i can be calculated based on the observed characteristics within the choice set. The characteristics in the choiceset are measured by the attributes and attribute levels. The error component ε_i cannot be measured, but is composed of random variables that can be described by a probability distribution. For random utility models, the utility expression can be described as in Equation 4-3.

Equation 4-3

$$U_{i=} V_i + \varepsilon i$$

The random component cannot be modelled, therefore the probability that individual *n* will choose alternative *i* in a choice set can be described as in Equation 4-4.

Equation 4-4

$$P_i = Prob(U_i > U_j) \forall j \neq i$$

The probability that an individual will choose alternative *i* is the probability that the utility of that alternative is greater than any of the other alternatives in the choice set.

4.5.2 Multinomial logit model

The multinomial logistic model (MNL) is a regression model that generalises logistic regression by allowing more than two discrete outcomes. MNL is derived under the premise that the error term is identically and independently distributed or Gumbel distributed. Gumbel distribution is a probability theory used to model the distribution of the maximum of a number of samples of various distributions. The probability of an individual choosing an alternative in an MNL model can be expressed by Equation 4-5.

Equation 4-5

$$P_i = \frac{e^{V_i}}{\sum_{j=1}^{J} e^{V_i}}$$

Where P_i is the probability the individual will choose alternative *i*. V_i is the deterministic component of the utility for alternative *i* and *J* is the number of alternatives in the choice set.

One of the most important features of the MNL model is that the ratio of probabilities of choosing any two alternatives is independent of the choice set. This is called the independence from irrelevant alternatives (IIA). The IIA for any two alternatives *i* and *k,* the ratio of the logit probabilities can be expressed as in Equation 4-6.

Equation 4-6

$$\frac{P_{ni}}{P_{nk}} = \frac{\frac{e^{V_{ni}}}{\sum_j e^{V_{ni}}}}{\frac{e^{V_{nk}}}{\sum_j e^{V_{nk}}}}$$

From Equation 4-6, the ratio of probability of individual *n* choosing either alternative *i* or *k* is related to the logit probability of an individual choosing such an option. Therefore, the ratio does not depend on any of the other alternatives. The only relevant alternatives in the ratio are *i* and *k.* There are a number of advantages with IIA. Firstly, if there is a large set of alternatives within a choiceset, the IIA allows for the ratio to be calculated as a subset. Secondly, if one is only interested in one ratio in a set of alternatives, the IIA allows for this to be estimated on this subset alone (Train (2003), Hensher et al (2005)). However, there are a number of disadvantages to IIA. Louvierre et al (2000) found that the IIA property can become unrealistic, when there are minimal differences between alternatives and can lead to biased estimates and incorrect predications. For example, a person is presented with the option of a car and red bus and that these two options have equal probability, 0.5, so the odds ratio sum to 1. Now add a third mode, of a blue bus, to the options. This assumes the colour of the bus has no bearings on the likelihood of choosing it or not. The person is expected to choose between bus and car still with equal probability, so the probability of car is still 0.5, while the probabilities of each of the two bus types is now 0.25. IIA implies that this is not the case: for the odds ratio between car and red bus to remain, the new probabilities must be car 0.33; red bus 0.33; blue bus 0.33. IIA does not take into account that red bus and blue bus are very similar. The differences between the alternatives examined in this study are not minimal and therefore an MNL model was judged to be appropriate.

When creating regression models it is important to create the models in a parsimonious fashion. A major goal when building regression models is to explain the variance of a model with the least amount of variables. Every time a variable is added to a model, it increases the complexity and the potential for correlation. It is best to avoid any unnecessary complications, unless there is a good theoretical theory behind the added complication. The less variables in a model, the better the performance of the model, however, there is a point where too few variables can affect the performance of the model negatively. It is important to run many combinations of a model and then judge when the model performs best, with the simplest combination of variables.

4.5.3 Maximum Likelihood Estimation of Discrete Choice Models

Maximum likelihood estimates are the set of population parameters that produce the observed sample most often. When a random set of n observations of a random variable Z denoted by $z_1, z_2, \ldots, z_n$ are drawn from a population characterised by parameter θ, the probability density function of Z given some values of θ, and if all the n values of Z in the sample are independent, then the joint probability density function can be estimated as in Equation 4-7.

Equation 4-7

$$f(z_1, z_2, \ldots, z_n|\theta) = f(z_1|\theta)f(z_2|\theta), \ldots, f(z_n|\theta)$$

The Zs in the function outlined in Equation 4-7 are assumed to be variable, and the θ fixed. This function could be changed to form a probability density function to a likelihood function, if the Zs are assumed to be fixed and the θ are assumed to be variable. It is possible to develop theories based on the populations that are characterised by the characteristic θ, based on some value of Z.

This can be extended to situations where populations are defined by more than one variable θ. The Zs have a normal distribution and are characterised by a mean (μ) and a variance (σ^2). By defining θ as a 2 dimensional vector with elements μ and σ^2 allows the likelihood function in Equation 4-7 to be maximised to a vector of θ.

Take a random sample of Q individuals, and for each of the individuals q there is an observed choice and these individuals choices have values of X_{jkq}. If individual q chooses i, the probability density function observed for that choice is $f(\text{Data}_q|\beta)$, where Data_q is the observed data for individual q and β is the vector of utility parameters contained in the observable component of utility V_{jq}. V_{jq} is the set of alternatives J observed by individual q. If all the observations are independent, $f(\text{Data}_q|\beta)$ can replaced in the likelihood function by the expression for probability of the alternative actually chosen by the individual. This is based on the assumption where n_1 individuals choose alternative 1, and n_2 individuals choose alternative 2, and so on. The likelihood function can be written as in Equation 4-8.

Equation 4-8

$$L = \prod_{q=1}^{n_1} P_{lq} \prod_{q=n_1+1}^{n_1+n_2} P_{2q}\,, \ldots, \prod_{q=Q-n_j+1}^{Q} P_{Jq}$$

If a dummy variable f_{jq} were to be introduced to Equation 4-8 then it could be simplified. This dummy variable would be equal to 1 if j is chosen, and 0 if it is not chosen. This simplification is displayed in Equation 4-9.

Equation 4-9

$$L = \prod_{q=1}^{Q} \prod_{j=1}^{J} P_{jq}^{f_{jq}}$$

The log likelihood of the previous two expressions is displayed in Equation 4-10, where $L*$ is maximised with respect to the βs contained in the utility equations which produce utility estimates for the alternatives under investigation.

Equation 4-10

$$L^{*} = \sum_{q=1}^{Q} \sum_{j=1}^{J} f_{jq} ln P_{jq}$$

The estimation of the models in this thesis were completed using NLogit 5. Econometric Software's NLogit software programme was selected to be used in the context of this analysis. There were other software packages available that can carry out aspects of the analysis required; however, NLogit was the only software package that combined all these aspects into one package. The main benefit NLogit has over the competitors is that it is possible to designate a "Choice" variable. This allows the relationships between the unchosen "Choices" and the chosen "Choice" to be identified. The software can identify the choices from which the choice was made. NLogit has a stronger set of supporting literature that allows for extensions and deviations from simple models to be easily formed. The NLogit software was also much more user friendly and contains an easily understood interface.

4.6 Discrete Choice Modelling Approach Applied

This section describes the methods of discrete choice modelling that are utilised in this study. These methods applied to the data collected can be observed in the models in Chapter 6.

4.6.1 Structure of the analysis

This section looks at the modelling approach used that resulted in the final models in this study. A step by step approach was used that allowed the progression of the models to be monitored in an accurate and coherent manner.

The first step in the structure of the analysis was to create a base model based on the estimates of the attributes and the attribute levels. The base model data contained estimates for each of the alternative options for time, weather, and route gradient. These base models can be seen for each of the data types in Sections 6.3.1, 6.4.1, 6.5.1 and 6.6.1 in Chapter 6.

Utility formulas that were created for the basic models that contained constants, time, weather and route gradient. The utility formulas estimate constants, then parameters for time. The parameters for weather and gradient were simplified as they were not numerically quantifiable. It was decided to simplify the weather parameter to a binary variable. This new weather variable was "Weather Dry". "Weather Dry" would be 1 if the weather was dry and 0 if it was not. This process was repeated for gradient. The new gradient variable is "Slope Flat". "Slope Flat" is 1 when the route gradient is flat and 0 when it is not flat. This allowed the regression models to be simplified, which is something that is very much desirable in regression modelling. The utility formula for the road without any cycling facilities can be viewed in Equation 4-11.

Equation 4-11

$$\begin{aligned} U(Road\ without\ facilities) &= Constant_{Road\ without\ facilities} \\ &+ \left((Time\ Parameter_{Road\ without\ facilities}) * Time\right) \\ &+ \left((Weather\ Dry\ Parameter_{Road\ without\ facilities}) * Weather\ Dry\right) \\ &+ ((Route\ Flat\ Parameter_{Road\ without\ facilities}) * Slope\ Flat) \end{aligned}$$

The utility formula for the road with cycle lanes can be seen in Equation 4-12.

Equation 4-12

$$\begin{aligned} U(Road\ with\ cycle\ lanes) &= Constant_{Road\ with\ cycle\ lanes} \\ &+ \left((Time\ Parameter_{Road\ with\ cycle\ lanes}) * Time\right) \\ &+ \left((Weather\ Dry\ Parameter_{Road\ with\ cycle\ lanes}) * Weather\ Dry\right) \\ &+ ((Route\ Flat\ Parameter_{Road\ with\ cycle\ lanes}) * Slope\ Flat) \end{aligned}$$

The utility formula for the segregated from traffic cycling facility can be seen in 4-13. NLogit requires that one of the utility formulas not have a constant in order to effectively model the formulas.

Equation 4-13

$$U(Segregated\ facility) = \left(\left(Time\ Parameter_{Segregated\ facility}\right) * Time\right) + \left(\left(Weather\ Dry\ Parameter_{Segregated\ facility}\right) * Weather\ Dry\right) + (\left(Route\ Flat\ Parameter_{Segregated\ facility}\right) * Slope\ Flat)$$

4.6.2 Introducing explanatory variables

Subsequent to the base models was the addition of explanatory variables. This allowed the base model to be extended to increase model fit and accuracy by including personal attributes of the respondents. This involved the addition of explanatory variables such as, age, gender, income, relationship status, etc, to the base models. Many extensions and different combinations were performed on the four data sources.

By including these variables it allowed for an understanding of how personal attributes affect the choices of the respondents. These personal variables were added to the basic utility formulas in Equations 4-11, 4-12, and 4-13. For modelling in NLogit, it was not possible to include variables of interest in all the formulas as this would result in the variable collapsing and becoming a constant in the model. However, the results of the variables for the other alternatives allow for the relationships to be inferred to the alternative without the variable.

4.7 Measuring the Performance of Discrete Choice Models

This section outlines the techniques in which the quality of the models in Chapter 6, were interpreted. Firstly, the parameter estimates from the models are explained and their interpretation is clarified. The statistical significance, pseudo R-squared, likelihood ratio test, and Akaike information criterion are then explained. Each one of the model performance estimations should not be used on their own, to determine whether a model is good quality or not. These estimations should be combined together as a judgement of the models, and then the analyst can gauge which model presents the best possible solution for the given context.

4.7.1 Sign of the coefficient

When interpreting the output table of a model, it is important to understand the sign of the parameter estimate. These signs should make intuitive sense. For example, time is a parameter estimate in the models in Chapter 6. One would expect as time would increase for an alternative, that the less likely an individual would choose this alternative. Therefore, it would be expected that the estimates for the time parameters in the models would be negative. Similarly, for the gradient variable, one would intuitively expect that the more flat an alternative, the more likely a respondent would select this option. Therefore, in the calculation of the gradient parameter estimates, it would be very surprising for the model to create a non-positive estimate.

4.7.2 Statistical significance

An important aspect in judging a models performance is the statistical significance of the individual parameter estimates. The statistical significance of each parameter estimate in a model is displayed in the column marked "|z|>Z*". Statistical significance is the estimated measure of the degree to which the parameter values estimated reflect the truth as to what is occurring within the population. Significance is represented in the form of a probability known as a *p*-value. The higher the *p*-value for a test, the less able one can conclude that the findings obtained may be inferred to a population. Typically, a *p*-value of 0.05 is generally accepted as the level of acceptable error for a regression model. This translates to there being a 5% probability that the relationship that has been identified in the research, does not exist within the study population (Hensher et al, 2005).

The statistical significance in NLogit is calculated from the standard error. The standard error in NLogit is the standard deviation of the sampling distribution of a parameter estimate. The standard error is used to create a *Z*-score. A *Z*-score is estimated from a *Z*-test. This *Z*-score is the number of standard deviations under which the null hypothesis can be approximated by a normal distribution. The null hypothesis is the general position that the relationship being tested does not exist. If the null hypothesis is rejected, then the relationship being tested exists. The formula for *Z*-test can be seen in Equation 4-14.

Equation 4-14

$$Z = \frac{A - B}{\sqrt{SE(A)^2 + SE(B)^2}}$$

Where *A* is one parameter estimate and B is another estimate. $SE(A)^2$ and $SE(B)^2$ are the standard errors calculated for each parameter estimate. The formula for calculating standard error can be seen in Equation 4-15.

Equation 4-15

$$SE = \frac{X - \mu}{Z}$$

Where *X* is the sample mean, and μ is the population mean, and *Z* is the Z score estimated in Equation 4-14. Having calculated the standard error, the statistical significance can then be estimated. The formula used to estimate statistical significance in NLogit can be seen in Equation 4-16 (Hensher et al, 2005).

Equation 4-16

$$P(|\mathrm{z}| > Z *) = \int_{-\infty}^{Z} \frac{1}{2\pi} \exp(\frac{1}{2} Z^2) dZ$$

Where Z* is the specific z statistic at the statistical level being tested. The statistical significance in the models tested is indicated at three levels. The levels are 0.01, 0.05, and 0.1. Significance at each one of these levels are indicated by "*", with a significance level of 0.01 indicated by "***", 0.05 indicated by "**" and 0.1 indicated by "*".

4.7.3 Pseudo R-squared

R-squared is the coefficient of determination. This coefficient indicates how good a line that has been created by the regression model to fit the data. It is a statistical measure of how well the regression line approximates the real data points. The closer this coefficient is to 1, the better the result. R-squared is calculated from dividing the residual sum of squares by the total sum of squares. From Hensher et al (2005), it is known that values in the range of 0.2 and 0.4 are normal and acceptable for MNL analysis.

This total sum of squares is the sum of the squares of the result of the observed values of the data points with the mean value of the data points from the regression model subtracted. This can be seen in Equation 4-17, where y_i is the observed value and $\bar{y}_j$ is is the mean of all the data points.

Equation 4-17

$$Sum\ of\ Squares_{Total} = \sum_i (y_i - \bar{y}_j)^2$$

The residual sum of squares is the sum of the squares of the result of the observed values of the data points with the predicted value for the data points from the regression model subtracted. This can be seen Equation 4-18, where f_i is the predicted value for the datapoint y_i.

Equation 4-18

$$Sum\ of\ Squares_{Residual} = \sum_i (y_i - f_i)^2$$

Equation 4-17 and Equation 4-18 are then used in the calculation of the R-squared. The formula for calculated R-squared is seen in Equation 4-19 (Hensher et al, 2005).

Equation 4-19

$$R^2 = 1 - \frac{Sum\ of\ Squares_{Residual}}{Sum\ of\ Squares_{Total}}$$

The R-squared estimated in NLogit is the pseudo R-squared value, and should only be used when comparing different models estimated from the same dataset, and not used in the comparison of models from other datasets (Bruin, 2006). The pseudo R-squared in NLogit is not indicative of the fit of a model, in relation to the data. It is however useful in the process of establishing the quality of the model being tested.

4.7.4 Akaike Information Criterion Coefficient

The Akaike Information Criterion coefficient (AICc) is the measure of the relative quality of a statistical model for a given set of data. This criterion estimates a coefficient by trading off the goodness of fit of the model to the data against the complexity of the model being hypothesised. This criterion is used in Chapter 6 when comparing models. This coefficient is used for comparing estimations of models within the same datasets (Hensher et al, 2005).

For example, when looking at the tourist dataset in Chapter 6, the AICc for the basic model is 1464.10, and the AICc for the extended model is 1444.00. The lower the AICc for a model, the better the model is for that dataset. Therefore, it can be seen for the tourist dataset, that the extended model provides a better trade off of goodness to fit and complexity than the basic model.

4.8 Willingness to Pay

Willingness to pay is the maximum amount a person would pay, exchange or sacrifice in order to; receive a good or service (pay for an item of clothing), or avoid something (pay a toll top avoid traffic). This section looks at the methodology behind the calculation of the willingness to pay of the different categories of people, for different standards of cycling facilities. The value of time used and why this value was chosen is also discussed.

The discrete choice models estimated in Chapter 6 can be used to calculate the willingness to pay of the individuals, for the different standards of cycling facilities The ratio of one parameter estimate of an alternative to another parameter estimate can be used to calculate the willingness to pay (Hensher et al, 2005). The estimation of the willingness to pay can be seen in Equation 4-20.

Equation 4-20

$$Willingness\ to\ Pay = \frac{\beta_{ia}}{\beta_{ib}}$$

Where β_{ia} is the parameter estimate for coefficient *i* for alternative *a,* and β_{ib} is the parameter estimate for coefficient *i* for alternative *b*.

4.8.1 Methodology used using Beta time

From Louvierre et al (2000), it is known that the value of time can be calculated when there are parameter estimates for both time and cost. This can be seen Equation in 4-21.

Equation 4-21

$$Value\ of\ Time = \frac{\beta_{time}}{\beta_{cost}}$$

This equation can be readjusted to allow for the estimation of either the cost or the time parameter, if the value of time is known and only one parameter has been estimated. As mentioned in Section 4-2, parameter estimates were created for time for each alternative in the various models. As time is known, Equation 4-21 can be rearranged to form Equation 3-22.

Equation 4-22

$$\beta_{cost} = \frac{\beta_{time}}{Value\ of\ Time}$$

In models such as those presented in Chapter 6 of this study, it is possible to create a ratio by using the different parameter estimates for the alternative cycling infrastructure. It was necessary to create cost coefficients from the models, so as to monetise the differences in choices.

The ratios between the different β_{costs} for the different alternatives can then be estimated. The alternative without any cycling facilities was chosen as the reference alternative. These ratios could then be computed with the value of time and the extra amount that an individual would be willing to pay, in comparison to the option without any cycling facilities. This could then be worked out.

4.8.2 Value of time

The value of travel time in Ireland is known to be €10.98 per hour (National Roads Authority, 2011). This is the value of time that was used in the estimation of the willingness to pay for all the models in Chapter 6. Research into the value of time of cyclists is presently quite restricted. There has been some attention given to the area of cyclists who commute, however, the value of time of tourist and recreational cyclists has not been developed. Wardman et al (2007) found in study of propensity to cycle to work that time spent cycling is valued almost three times more than other modes. It was also found that this value of time would vary depending on the quality of cycling facilities upon which one would cycle. The value of time generally reduces with the increasing quality of cycling facilities. The values of time found by Wardman et al (2007) calculated a value of time for cyclists of €18.17 per hour. Börjesson and Eliasson (2012) also conducted some research into the area of the value of time of cyclists in Sweden and found similar results to Wardman et al (2012). It was found that the value of time for cyclists was quite high and was actually higher than all the other modes of transport in the study. The study was carried out in Sweden and the value of time was found to be €16 per hour for cyclists who cycle along a street and €11 per hour for those using a separated bike lane. These values were nearly twice as high as the next highest value for time of another mode of transport.

The figure of €10.98 per hour from the National Roads Authority (2011) seems to be at the appropriate level for cycling value of time. It is important that an Irish value of time be used as values of time vary greatly from country to country and therefore, it was decided that €10.98 would be used in this study.

4.9 Health Economic Analysis

This section presents the theory that undermines the health economic analysis that is used in this thesis. The theory reported in this section was used in Chapter 7.

4.9.1 Health Economic Assessment Tool

The Health Economic Assessment Tool (HEAT) was developed by the WHO in 2011 (WHO, 2012). The HEAT tool was specifically developed to measure the health benefits of cycling and to place an economic value on these benefits (WHO, 2012). The purpose of this tool is to create an economic assessment of cycling infrastructure and policies. This tool can be used to examine both existing infrastructure and policies, and analyse the potential benefits of proposed infrastructure and policies. The HEAT calculations estimated in this thesis were formed by combining results from the survey undertaken in the study area, and the census statistics from 2011 for the study area.

The HEAT tool was selected over other similar appraisal tools as it is based on an extensive review by the WHO. The WHO performed a systematic review of economic and health literature from around the world, that examined assessments of various transport projects and epidemiological literature concerning the various health effects that accrue from cycling. The review was based on academic research, government reports and other relevant literature which allowed for this comprehensive tool to be created and applied around the world. The tool is easily adapted and allows national and local factors, such as mortality rates, inflation rates, current travel modes, and the relevant value of a statistical life to be included in the analysis. This allows the tool to be included in analysis around the world, as the applicable local effects can be incorporated. The results of the tool can be easily understood, and used in comparisons of similar projects around the world. For more information on measuring the health benefits of cycling please see Chapter 2.

4.9.2 Economic Savings from a Reduction in Mortality

The HEAT tool was created as a way to measure the economic impact of combating physical inactivity, which is a significant health problem in many regions of the world. The solution to this problem is not simple and requires a macroscopic view on all aspects of day to day living. One area that has been identified as having the potential for increasing physical activity is transport. In order to increase active travel, this area needs to be fully understood. The HEAT tool allows an understanding of proposed health benefits of active travel to be developed and then to be financially quantified.

In many cases, the financial benefits derived from increased cycling from a new policy or new piece of cycling infrastructure may not have direct tangible financial benefits. For instance, when a new toll road is proposed, the main financial benefits can be attributed to time savings, reduction in traffic, etc, and the payment of the tolls are a direct and easily quantifiable way of determining the return on the investment. For the type of analysis considered in this chapter, the economic gains are derived mostly from increased health benefits. The calculation of the return on a potential investment from increased health can be a very difficult issue to assess, however HEAT provides a methodology to measure these economic impacts. Increasing the health of a population as a whole, usually leads to several marked improvements in many areas. For instance, if the working population is healthier, then there are less sick days taken annually and therefore the population becomes more productive (WHO, 2012). Another aspect is a reduced mortality rate. By reducing the mortality rate, more people are living and working longer. This healthier population also results in a decrease in the cost of running the health services, as there will be less demand from a healthier population (WHO, 2012). The HEAT tool factors these benefits into the financial analysis of an investment in infrastructure or policy.

4.9.3 HEAT Evaluation

The process required for HEAT can be seen in the following steps:

1. HEAT needs to be informed whether this is analysis of a single point in time or whether there is a before and after scenario being tested. For the analysis performed in this thesis, a before and after with an intervention is tested.
2. Following this, it is necessary to input the pre-intervention information. This requires the average number of cycling trips per person. In order to do this, data on the number of cycling trips per day, number of cycling trips per year and the average distance of these trips needs to be computed. Having calculated the average trips embarked on per person, the average distance of the trip along with the number of people of undertaking these trips is required.
3. The reduced mortality rate for those currently cycling is calculated. This will form the baseline from which the mortality rate is calculated and from this the post information data can be compared.
4. It is then necessary to input the post intervention data. This section requires the predicted increase or decrease from an intervention in the following areas:
    a. Average number of cycling trips per day.
    b. Average number of days per year where there are cycling trips.
    c. Average distance of cycling trips.
    d. Number of people that would undertake cycling trips.
5. Subsequent to this the pre and post intervention data inputted into the analysis, a summary of the cycling data is produced that outlines how the present rate of cycling is reducing the mortality rate, and how the predicted level of cycling would reduce the mortality rate. One is now able to make a basic comparison between pre and post intervention looking solely on mortality
6. Succeeding the cycling summary, it is necessary to enter the information on the intervention. This requires a compilation of the following data:
    a. Proportion of increased cycling attributable to the intervention.
    b. The time period required for the maximum uptake in cycling.
    c. Present mortality rate in the country.
    d. Present statistical value of life in the country.

    e. The time period over which the benefits are calculated.

7. The details on the exact costs of the intervention and the discount rate to factor in inflation are then needed.
8. Once all the preceding steps have been completed, the tool produces the HEAT calculation from which the following information can be viewed:
    a. Decrease/increase in mortality rate.
    b. Reduction/expansion of the number of deaths per year in the study population.
    c. Average annual benefit.
    d. Total benefits accumulated over study time period specified.
    e. Benefit cost ratio based on the cost of the intervention.

From these steps, it can be seen by combining a stated preference survey with the census results would produce a very effective way of producing the HEAT calculation.

4.9.4 Census Statistics and Stated Preference

The design and layout of the HEAT tool was studied and the logic behind the process was mapped. This allowed the key questions to be identified, along with the shortest method through the logic process. The shortest method was chosen so as to minimise respondent fatigue. For the present day evaluation of cycling benefits, information was required on the number of trips per day, per person, and the number of days on average a person cycles. The average distance of these trips, and the number of people undertaking these trips also needed to be identified. From this, a baseline was established, from which, the benefits of an intervention (new cycling infrastructure) could be determined. Following from the establishment of a baseline, information on the potential and predicted usage from an intervention is necessary. The information required is the same as the pre-intervention data, except that this data is what is predicted and therefore determines the potential benefits.

In Figure 4-2, the questions used to extract the necessary information can be seen. The questions posed were in relation to the regularity of present day cycling of the cycling, and commute distance and time. The respondents were presented with “What if” questions in relation to the creation of a high quality cycling facility along the proposed cycle route. The other questions posed in the survey can be viewed in Appendix 3.

Section 1 - General Questions

*** Do you presently cycle to and from NUIM?**

- Yes
- No

How far from NUIM do you live?

- Less than 3km
- Between 3km and 5km
- Between 6km and 10km
- Between 11km and 20km
- Over 20km
- Work from home

Other (please specify)

What is your travel time to NUIM?

- Less than 5 minutes
- Between 6 minutes and 10 minutes
- Between 11 minutes and 20 minutes
- Between 21 minutes and 40 minutes
- Over 40 minutes
- Work from home

Other (please specify)

If a High Quality Cycling Facility Existed in your Area

Segregated from Traffic, High Quality Cycling Facility:

*** If a high quality Greenway/cycle path like the one pictured above was constructed along the Royal Canal Towpath with direct access to NUIM, would you use this facility: (The facility would be fully seperated from vehicular traffic)**

	Yes	No
To access NUIM?	○	○
For recreational/shopping purposes?	○	○

*** And how often would you use the facility for commuting to and from your place of work or education?**

- Almost every day
- 1-2 times a week
- 1-2 times a month
- 1-2 times a year
- Never

Figure 4-2 Screenshot of Questions Pertaining to the HEAT Analysis

The personal information and demographic information of the study population can be retrieved from a national census that was carried out in April 2011. The census statistics were gathered from the POWSCAR dataset which is produced by the Central Statistics Office in Ireland (Central Statistics Office, 2012). This dataset is compiled from anonymised records from a national census undertaken on the night of the 10th of April, 2011.

The HEAT questions used in the stated preference survey provides a broad representation of the study population. The results from this survey can then be scaled and applied to the study population and the results from this can be used in the HEAT evaluation.

4.10 Summary

This chapter presents the processes used to produce the results presented in Chapter 6 and Chapter 7. A discussion on the appropriateness of these results is presented in Chapter 6 and Chapter 7. The reliability of the methods and how these could be improved upon car also discussed in these conclusion chapters.

5 Summary of Survey Statistics

5.1 Introduction

This chapter contains a summary of the data collected from the tourist and the study area surveys, undertaken in 2012 and 2013. The results of the surveys are split into two distinct sections. The details of the collection can be seen in Chapter 4. The first section outlines the results of the survey carried out among tourists in the summer of 2012, and the second section outlines the results of the surveys carried out in the study area, in the winter of 2012 and 2013. Within these two sections there are several smaller segments. The tourist survey results are divided into three sections, and the study area survey results is divided into four sections.

The tourist survey results were arranged into:

1. Cycling and Tourism.
2. Scenarios Chosen.
3. Socio-Economic Information.

The study area survey results were arranged into:

1. Cycling and the Study Area.
2. Health Economic Results.
3. Scenarios Chosen.
4. Socio Economic Information.

The results for the tourist surveys and the study area surveys can be viewed in the following sections in this chapter.

5.2 Tourist Survey Results

This section presents the results from the tourist surveys that were undertaken in summer of 2012. In total, there were 287 valid responses. The results for the tourist survey are presented in three sections: The first section presents the questions that were put forward to the tourist respondents relating to cycling and tourism. The second section presents the findings from the scenarios presented to the tourist respondents. Lastly, the third section outlines the personal demographic information of the tourist respondents.

5.2.1 Cycling and Tourism Responses

This section outlines the results from the questions posed in the tourist survey, that relate to tourism and cycling. The results in this section include reasons for visiting Ireland, length of stay while visiting Ireland, cycled while in Ireland, first visit to Ireland, visit Ireland again, etc. The full collection of results can be viewed in the following sections.

Reason for Visiting Ireland

It can be seen that the main reason for visiting Ireland for the respondents was for "Holiday/Recreation", with 85% of the respondents citing this as the main reason. The remaining 15% cited business purposes, visiting friends/family and a combination of purposes.

Table 5-1 Main Reason for Visit

Main reason for this Visit?	Number	Percentage
Holiday/Recreation	244	85
Business	4	1
Visiting friends/relatives	11	4
Mix	17	6
Other (please specify)	10	4
No response	1	0
Total	287	100

Length of Stay in Ireland

It can be seen that the largest category for length of stay was those staying in Ireland for 9 to 12 days, with 30% stating that the length of their trip was in this range. 24% of the respondents were staying for longer than 12 days, and another 24% were staying for less than 5 days. 18% stayed for between for between 5 and 8 days.

Table 5-2 Trip Length

Trip Length	Number	Percentage
Less than 5 days	70	24
5 to 8 days	53	18
9 to 12 days	85	30
More than 12 days	69	24
No response	10	4
Total	287	100

Plan on Cycling or Have Cycled While in Ireland

It can be seen that 20% of the respondents either cycled or planned on cycling while they were visiting Ireland, with 78% stating that they did not plan on cycling while in Ireland.

Table 5-3 Cycled in Ireland

Cycled while in Ireland?	Number	Percentage
Yes	56	20
No	225	78
No response	6	2
Total	287	100

Recommend Ireland from your Experience of Cycling in Ireland

It can be seen that 30% of the respondents would recommend Ireland from their experience of cycling, and 18% would not recommend Ireland from their experience. 52% of the respondents did not answer this question.

Table 5-4 Recommend Ireland from Experience of Cycling in Ireland

Recommend Ireland from experience of cycling?	Number	Percentage
Yes	85	30
No	51	18
No response	151	52
Total	287	100

Would Improvements to Cycling Facilities Encourage Another Visit?

It can be observed that 35% of respondents would be encouraged to visit Ireland again if there were improvements made to the cycling infrastructure, with 17% stating that this would not encourage them to visit again. 48% of the respondents did not answer this question.

Table 5-5 Improvement to Cycling Facilities Encourage Revisit

Improvements to cycling facilities encourage revisit	Number	Percentage
Yes	100	35
No	48	17
No response	139	48
Total	287	100

Utilisation of a high quality Greenway near Accommodation

It can be seen that 72% of the respondents would utilise a high quality greenway if it were near where they were staying, with only 5% stating that they would not use this facility. 23% of the respondents did not answer this question.

Table 5-6 Greenway near Accommodation

If where staying high quality Greenway, use it?	Number	Percentage
Yes	207	72
No	14	5
No response	66	23
Total	287	100

Accommodation Chosen due to Proximity of a High Quality Greenway

The respondents were asked whether they would choose accommodation due it being near a high quality greenway over accommodation that was not. It can be seen that 63% would select accommodation near a greenway, whereas 18% would not. 19% of the respondents did not answer this question.

Table 5-7 Choose Accommodation near Greenway

Choose a hotel near a high quality greenway/ cycle path over one that is not?	Number	Percentage
Yes	181	63
No	52	18
No response	54	19
Total	287	100

5.2.2 Scenarios Choices

Following the section of the survey relating to cycling and tourism, the respondents were presented with a section that contained four scenarios. The respondents were asked to imagine that they were in a situation where they were sightseeing by bicycle, in rural

Ireland, and they were travelling between two locations. Between the two locations, there are three possible routes upon which they can travel, but each has varying conditions attached. The three options were as follows:

1. Option A: A road with no cycling facilities – shared space with vehicular traffic.
2. Option B: An on-road cycle lane – Lane separate to traffic with some vehicular interaction.
3. Option C: A fully segregated cycling facility – facility with little or no interaction with vehicular traffic.

As there were four scenarios, each respondent provided four answers; therefore, there were 1,148 responses (287 x 4). It can be seen for this section than "Option A - Road without Cycling Facilities" received only 7% of the choices, with "Option B – Road with Cycling Lanes" receiving 18% of the choices, and "Option C – Segregated from Traffic Cycling Facility" receiving 73% of the choices.

Table 5-8 Options Chosen

Facilities Chosen	Number	Percentage
Option A – Road without Cycling Facilities	78	7
Option B – Road with Cycling Lanes	205	18
Option C – Segregated from Traffic Cycling Facility	845	73
No response	20	2
Total	1,148	100

5.2.3 Socio Economic Results from Tourist Survey

The socio-economic characteristics of the respondents are presented in this section. This section outlines the results relevant to gender, age, country of residence, income, cycling in country of residence, bicycles in household, etc. All the socio-economic results can be viewed in the following sections.

Gender

The results indicate that 39% of the respondents were male and 59% of the respondents were female, therefore the gender category is skewed slightly, as there were more female respondents than male.

Table 5-9 Gender of Respondents

Gender	Number	Percentage
Male	112	39
Female	169	59
No response	6	2
Total	287	100

Age

The age category of 12-24 years has the largest percentage of responses, with 40% of the respondents being in this age group. This could be attributed to some of the surveys being undertaken in a hostel (most likely due to the average age of guests in a hostel being lower than the average age of tourists visiting the country). This age grouping is also the largest with the age range covering 12 years, whereas the other age ranges covered 10 years.

Table 5-10 Age of Respondents

Age	Number	Percentage
12-24	114	40
25-34	68	24
35-44	21	7
45-54	35	12
55-64	29	10
65+	13	5
No response	7	2
Total	287	100

Relationship Status

It can be observed that those who are single account for the greatest proportion of respondents at 48%, however, if the categories of “Married” and “In a relationship” were to be combined into one group, these would then account for 49%.

Table 5-11 Relationship Status of Respondents

Relationship Status	Number	Percentage
Single	137	48
Married	86	30
In a relationship	54	19
Other (please specify)	1	0
Missing	9	3
Total	287	100

Country of Residence

It can be seen that the majority of the respondents originated from within Europe, with 6% of the respondents indicating that they were from Great Britain, and 47% indicating that they were from elsewhere in Europe. 30% of the respondents were from either the USA or Canada.

Table 5-12 Country of Residence

Where from?	**Number**	**Percentage**
Great Britain	16	6
Other Europe	136	47
USA and Canada	86	30
Other areas	43	15
No response	6	2
Total	287	100

Cycling in Country of Residences

It can be seen that 32% of the respondents cycle for commuting to and from their places of work and education in their country of residence, whereas 53% do not. 70% of the respondents cycle for recreational purposes in their country of residences, and 21% do not.

Table 5-13 Cycling in Country of Residence

In your country of residence, do you cycle for:		
(a.) Work/Education purposes?	**Number**	**Percentage**
Yes	92	32
No	151	53
No response	44	15
Total	287	100
(b.) Recreational purposes?	**Number**	**Percentage**
Yes	201	70
No	59	21
No response	27	9
Total	287	100

Income

The respondents were questioned about their income, but were given the option of not disclosing this information. 65% of the respondents selected the option of not disclosing their information. It can be seen that 12% of the respondents had a household income of over €100,000, and 9% of the respondents had a household income of less than €10,000.

Table 5-14 Income of Respondents

Income	Number	Percentage
Less than €10,000	15	5
Between €10,000 and €49,999	33	11
Between €50,000 and €99,999	17	6
More than €100,000	35	12
Rather not Say	187	65
Total	287	100

Number of Bicycles in Household

It can be observed that 12% of the respondents do not have any bicycles in their household, in their country of residence. This increases to 19% for households with one bicycle, 25% for households with two bicycles and 30% for households with three or more.

Table 5-15 Bicycles in Household

Bikes in Household	Number	Percentage
Zero	34	12
One	54	19
Two	73	25
Three or more	87	30
No response	39	14
Total	287	100

Confidence as a Cyclist

It can be seen that 53% of the respondents rated themselves as either confident or very confident cyclists, with 7% and 1% choosing to describe them as nervous and very nervous respectively.

Table 5-16 Confidence as a Cyclist of Respondents

Confidence as a Cyclist	Number	Percentage
Very Confident	54	19
Confident	98	34
Reasonable	62	22
Nervous	19	7
Very nervous	2	1
Missing	52	18
Total	287	100

Education

It can be seen that there was a reasonably even spread of response in relation to education, without any level receiving an overly large amount or a very low amount of responses. 24% of the respondents had graduate degrees or higher. 26% had an education level of high school or lower.

Table 5-17 Education of Respondents

Education	Number	Percentage
High school or Lower	74	26
Diploma	30	10
Bachelor Degree	73	25
Graduate Degree or Higher	68	24
Missing	42	15
Total	287	100

5.2.4 Discussion of Tourist Survey Results

One of the stand out responses for the tourist survey results was the level of cycling that was planned or cycling that was undertaken amongst tourists visiting Ireland. It can be seen that 20% of the respondents indicated that they planned to cycle or had cycled in Ireland. This high level could be due to the tourist surveys being undertaken in Dublin, where there is a very successful bike sharing scheme, that is relatively cheap, user friendly and popular. This easy accessible bike sharing scheme is most likely the main reason for the high level of cycling reported, however, it is indicative that under the right conditions with appropriate cycling infrastructure, there is potential for a large proportion of tourists willing to travel by this mode. Another interesting result was that 63% of the respondents would select accommodation near high quality cycling infrastructure over accommodation that wasn't. This also indicates that there is a strong desire among tourists to cycle when sightseeing.

From this observation of the tourist survey results it becomes apparent that there is a definite potential for providing cycle infrastructure and facilities that cater for tourists. Under the correct conditions, there could be quite a high level of cycling among tourists achieved.

5.3 Study Area Survey Results

This section presents the results from the surveys that were undertaken in the winter of 2012/2013. In total, there were 845 valid responses. The results for this survey are grouped into four sections. The first section describes the cycling habits and the study area. The second section states the results from the questions relating to the health economic analysis. The third section reports the results from the scenarios section of the survey. The fourth section outlines the socio-economic information of the respondents to the study area survey.

5.3.1 Respondent's Relationship with Cycling and the Study Area

This section reports on the results of the questions posed to the respondents relating to cycling in the study area, and the respondents relationship with cycling. This section looks at the cycling rates to and from work/education, frequency of cycling, rating of cycling facilities in the study area, etc. The full results from the questions posed on cycling and cycling in the study area can be seen in the following sections.

Cycle to and from Work/Education

It can be seen that 27% of the respondents cycle to and from their places of work and education, and 73% of the respondents did not cycle. Each respondent provided an answer for this question.

Table 5-18 Cycle to and from Work/Education

Cycle for Work/Education purposes	Number	Percentage
Yes	228	27
No	617	73
No response	0	0
Total	845	100

Mode of Transport if not Cycling

This table shows that the main mode of transport for those that do not cycle is the motor vehicle, with 41% of the respondents travelling by this mode as either a driver or as a passenger. It can be seen that using the train has the lowest modal share at 8%. The "Missing" category can be attributed to those who cycle.

Table 5-19 Mode of Transport for Accessing Work/Education if not Cycling

Don't cycle for work/education purposes, what mode used	Number	Percentage
Motor Vehicle (Driver)	315	37
Motor Vehicle (Passenger)	32	4
Walk	129	15
Bus	77	9
Train	64	8
Missing (Those whom cycle)	228	27
Total	845	100

Cycle for Recreational Purposes

It was interesting to note that a sizeable amount of the respondents indicated that they cycle for recreational purposes. 55% of the respondents indicated that they cycle for recreational purposes and 33% indicated that they did not.

Table 5-20 Cycle for Recreational Purposes

Cycle for Recreational purposes	Number	Percentage
Yes	466	55
No	274	33
No response	105	12
Total	845	100

Cycling Experience in Local Area

It can be seen that just 16% of the respondents would categorise their experience of cycling in the area as either safe or very safe, and 28% categorised cycling in their local area as either dangerous or very dangerous. 46% of the respondents did not provide a response.

Table 5-21 Experience of Cycling in Study Area

Experience of Cycling in Study Area	Number	Percentage
Very safe	19	2
Safe	122	14
Neutral	93	11
Dangerous	176	21
Very dangerous	49	6
Missing	386	46
Total	845	100

Rating of Cycling Facilities in Study Area

Only 1% of the respondents rated the cycling facilities in their area as excellent, and 10% rated them as satisfactory. 31% of the respondents rated the cycling facilities in their area as either inadequate or very inadequate.

Table 5-22 Rating of Cycling Facilities in Study Area

Rating of Cycling Facilities in area	Number	Percentage
Excellent	12	1
Satisfactory	82	10
Neutral	104	12
Inadequate	133	16
Very inadequate	128	15
Missing	386	46
Total	845	100

5.3.2 Results for the Health Economic Analysis Questions

This section outlines the results from the questions posed in the survey within the study area, specifically designed to solicit information that would be used for the health economic analysis. These results would be used in the health economic analysis and allow for the determination of the health economic effects from increased cycling, from the construction of the proposed cycle route. The first section investigates whether a high quality greenway segregated from traffic would be used for commuting. The second section examines whether this facility would be used for recreational purposes. The final section considers the regularity of use of the greenway for commuting.

Use of Greenway for Commuting to and from Places of Work and Education

It can be seen that 56% of the respondents indicated that they would utilise a greenway that was fully segregated from traffic for commuting to and from places of work and education, if it were constructed. 24% would not use it for commuting.

Table 5-23 Use Greenway for Commuting

Use a Greenway Segregated from Vehicular for Commuting	Number	Percentage
Yes	472	56
No	199	23
Missing	174	21
Total	845	100

Use of Greenway for Recreational Purposes

It can be seen that 60% of the respondents indicated that they would use a greenway that was segregated from traffic for recreational purposes, and 19% of the respondents would not. 21% of the respondents did not respond to this question.

Table 5-24 Use Greenway for Recreational

Use a Greenway Segregated from Vehicular for Recreational Purposes	Number	Percentage
Yes	505	60
No	159	19
Missing	181	21
Total	845	100

Frequency of Use of Greenway

It can be seen that 28% of the respondents indicated that they would utilise a greenway that was segregated from traffic almost every day, and only 13% of the respondents said they would never use it. 16% of the respondents did not provide a response for this question.

Table 5-25 How Often Use Greenway

How Often Use the Facility for Commuting	Number	Percentage
Almost every day	233	28
1-2 times a week	194	23
1-2 times a month	120	14
1-2 times a year	57	7
Never	109	13
Missing	132	16
Total	845	100

5.3.3 Scenario choices

Following the section of the survey relating to cycling and respondents, and health economic question, the respondents were presented with a section that contained four scenarios. The respondents were asked to imagine that they were in two situations. The first situation was that they were commuting between their place of work/education and their place of residence. Between their place of residence and place of work/education, there are three possible routes upon which they can travel, but each has varying conditions attached. The three options were as follows:

1. Option A: A road with no cycling facilities – shared space with vehicular traffic.

2. Option B: An on-road cycle lane – Lane separate to traffic with some vehicular interaction.
3. Option C: A fully segregated cycling facility – facility with little or no interaction with vehicular traffic.

The respondents were asked to choose one option given the varying conditions. Following this choice, they were then asked to imagine they were embarking on a recreational trip. They were then asked to make the choice from the given options and conditions for a recreational trip. This was repeated for the other three scenarios presented to the respondents. As there were four scenarios, each respondent provided eight responses. There were four responses for the commute trip, and four responses for the recreational trip. Therefore, there were 3,380 responses (2845 x 4) for both trip purposes.

Commute Trip

It can be seen in this section that for the commute trips, "Option A - Road without cycling facilities" received only 10% of the choices, with "Option B – Road with Cycling Lanes" receiving 22% of the choices, and "Option C – Segregated from Traffic Cycling Facility" receiving 47% of the choices. 21% of the respondents did not provide an answer.

Table 5-26 Facilities Chosen for a Commute Trip

Facilities Chosen – Commute Trip	Number	Percentage
Option A - Road without cycling facilities	349	10
Option B - Road with Cycling facilities	728	22
Option C - Segregated from Traffic Cycling Facility	1,599	47
No response	704	21
Total	3,380	100

Recreational Trip

It can be seen in this section that for the recreational trips, "Option A - Road without cycling facilities" received only 10% of the choices, with "Option B – Road with Cycling Lanes" receiving 16% of the choices, and "Option C – Segregated from Traffic Cycling Facility" receiving 53% of the choices. 21% of the respondents did not provide an answer for this section of the survey.

Table 5-27 Facilities Chosen for a Recreational Trip

Facilities Chosen – Recreational Trip	Number	Percentage
Option A - Road without cycling facilities	353	10
Option B - Road with Cycling facilities	544	16
Option C - Segregated from Traffic Cycling Facility	1,779	53
No response	704	21
Total	3,380	100

If Conditions Were the Same, Which Option?

The respondents were questioned as to which option they would choose if the conditions were the same for all the options. It can be seen that 64% of the respondents would select Option C, 11% would select Option B, and 1% would select Option A.

Table 5-28 Conditions the Same, Which Option

All Conditions the Same, Which Option	Number	Percentage
Option A – Road with no cycling facilities	11	1
Option B – Road with cycle lanes	92	11
Option C – Fully segregated facility	542	64
Missing	200	24
Total	845	100

Condition with Biggest Impact for a Commute Trip

The respondents were questioned regarding which condition was the biggest influencing factor in the decision for choosing the options for a commute trip. It can be seen that 40% of the respondents stated that time was the greatest factor, with 21% stating that weather would have the biggest impact, and 13% stating route slope. 26% of the respondents did not answer this question.

Table 5-29 Conditions with Biggest Impact on Commute Trip

Condition with Biggest Impact for a Commute Trip	Number	Percentage
Time	337	40
Weather	178	21
Route Slope	112	13
Missing	218	26
Total	845	100

Condition with Biggest Impact for a Recreational Trip

The respondents were questioned as to which condition was the biggest influencing factor in the decision for choosing the options for a recreational trip. It can be seen that 16% of the respondents stated that time was the greatest factor, with 36% stating that weather would have the biggest impact, and 26% stating route slope. 26% of the respondents did not answer this question.

Table 5-30 Conditions with Biggest Impact on Recreational Trip

Conditions with the Biggest Impact for a Recreational Trip	Number	Percentage
Time	137	16
Weather	305	37
Route Slope	180	21
Missing	222	26
Total	845	100

5.3.4 Socio Economic Results from Study Area Survey

The socio-economic characteristics of the respondents to the study area survey are presented in this section. This section outlines the results on gender, age, country of residence, income, bicycles in household, etc. The full collection of socio-economic results can be seen in the following sections.

Gender

The gender profile is skewed slightly as there were more female respondents than male. It can be seen that 36% of the respondents were male and 39% were female.

Table 5-31 Gender of Respondents

Gender	Number	Percentage
Male	304	36
Female	327	39
No response	214	25
Total	845	100

Age

The age category of 12-24 years has the largest percentage of responses. This could be attributed to some of the surveys being undertaken in a university (student population being predominantly under the age of 24). It can be seen that those in the age category of 12-24 accounted for 30% of the respondents.

Table 5-32 Age of Respondents

Age	Number	Percentage
12-24	256	30
25-34	111	13
35-44	122	14
45-54	93	11
55-64	35	5
65+	14	2
No response	214	25
Total	845	100

Relationship Status

It can be seen that 29% of the respondents were single, with 43% being either in a relationship or married. 28% of the respondents did provide an answer for this question.

Table 5-33 Relationship Status of Respondents

Relationship Status	Number	Percentage
Single	238	29
Married	193	23
In a relationship	169	20
Missing	235	28
Total	845	100

Income

It can be seen that 9% of those surveyed had a household income of less than €10,000. As mentioned in the section detailing age, the survey was undertaken in a university campus and therefore there may be an over representation of students who may not have a high income. 5% of the respondents had a household income of more than €100,000. 19% of the respondents chose not to provide an answer for this question.

Table 5-34 Income of Respondents

Income	Number	Percentage
Less than €10,000	76	9
Between €10,000 and €30,000	77	9
Between €30,000 and €50,000	80	10
Between €50,000 and €70,000	63	8
Between €70,000 and €100,000	83	10
More than €100,000	45	5
Rather not say	164	19
Missing	257	30
Total	845	100

What Distance Residence from Place of Work and Education

25% of respondents live within 3km of their place of work and education, with 27% living over 20km away. It can be seen that 45% of the respondents live within 10km of their place of work and education.

Table 5-35 Distance from Place of Work and Education

Distance Residence is from Place of Work/Education	Number	Percentage
Less than 3km	215	25
Between 3km and 5km	60	8
Between 6km and 10km	107	13
Between 11km and 20km	117	14
Over 20km	232	27
Work from home	3	0
Missing	111	13
Total	845	100

What Travel Time Residence is from Place of Work and Education

It can be seen that 7% of the respondents' travel time to and from their place of work and education is 5 minutes. 22% of the respondents indicated that their travel time to and from their place of work and education is over 40 minutes.

Table 5-36 Time Residence is from Place of Work and Education

Time Residence is from Place of Work/Education	Number	Percentage
Less than 5 minutes	59	7
Between 6 minutes and 10 minutes	132	16
Between 11 minutes and 20 minutes	168	20
Between 21 minutes and 40 minutes	193	23
Over 40 minutes	185	22
Work from home	2	0
Missing	106	12
Total	845	100

Educational Level of Respondents

It can be seen that 30% of the respondents' education was in the "Post- Primary or Lower" category. As mentioned previously, many respondents originated from with a university campus, and therefore those in undergraduate study may not have a level of education higher than this at the time the survey was undertaken. 13% of the respondents had a graduate degree and 26% had a graduate degree or higher.

Table 5-37 Education Level of Respondents

Education	Number	Percentage
Post-Primary or Lower	253	30
Diploma	69	8
Bachelor Degree	113	13
Graduate Degree	192	23
Missing	218	26
Total	845	100

Confidence as a Cyclist

It can be observed that 50% of the respondents would rate their confidence as a cyclist as being either confident or very confident. 12% of the respondents rated their confidence as a cyclist as being either nervous or very nervous. 1% of the respondents did not have an opinion on the matter.

Table 5-38 Confidence as a Cyclist of Respondents

Confidence as a Cyclist	Number	Percentage
Very Confident	167	20
Confident	251	30
Reasonable	215	26
Nervous	70	8
Very Nervous	36	4
No Opinion	10	1
Missing	96	11
Total	845	100

Bicycles in Households

It was found that only 7% of the respondents belonged to a household that did not have any bicycles, whereas 67% of households had access to at least one bike. 26% of the respondents did not provide an answer for this question.

Table 5-39 Number of Bicycles in Respondents' Household

Bikes in Household	Number	Percentage
Zero	63	7
One	166	20
Two	171	20
Three or more	225	27
No response	220	26
Total	845	100

5.3.5 Discussion of Study area Results

There were many areas of this survey that provided intriguing insights regarding the respondents in the study area survey. Just looking at the scenarios section alone provides information relating to the preferences of the respondents. It could be seen that 10% of the respondents selected to travel along a road without any cycling infrastructure, for both commute trips and recreational trips, implying that those selecting this option were reluctant to change from infrastructure when the trip purpose changed. However, some of those that were selecting the road with cycle lanes were willing to change to a segregated facility, when the trip purpose changed from commute to recreational. The proportion of respondents choosing road with cycle lanes reduced from 22% to 16%, when the trip purpose changed from commute to recreational, and the segregated facility increased from 47% to 53% when the trip purpose changed.

Another interesting aspect that this section presented was relevant to the conditions that had the biggest impact on the choice of infrastructure, for the two different trip purposes. For the commute trip, 40% of the respondents indicated time had the biggest impact on the choice of infrastructure, and 21% and 13% of the respondents indicated that weather and route slope respectively, had the biggest impact on the choice of infrastructure. For the recreational trip, 36% of the respondents indicated that weather had the biggest impact on the choice of infrastructure, and 21% and 16% of the respondents indicated that route slope and time respectively, had the biggest impact on the choice of infrastructure. It can be seen that time went from the biggest impact for the commute trip to the factor having the least impact for a recreational trip.

This section indicates that there is a large potential for cycling in the study area, however this is reliant on several conditions. One of the main conditions is that there needs to be better cycling infrastructure and facilities provided in the area. The proposed cycle route will go some way to improving the infrastructure for the area, however, there needs to be other cycling infrastructure that can link in with this proposed route. If the proposed cycle route was the first phase of a programme providing cycling infrastructure in the area, then there would be definite scope for large scale increases in the cycling rate, for both commute and recreational purposes.

5.4 Summary

This chapter presents a summary of the statistics from the two surveys that were used in this thesis. The results in this chapter include statistics on the following: mode of transport used, opinion of existing cycling infrastructure, opinion of potential cycling infrastructure, socio-economic information and qualitative responses. The purpose of this chapter was to provide guidance when interpreting the variables which are analysed in Chapter 6. The results presented are the general statistics collected from the surveys, and the analysis on these statistics is conducted in Chapter 6.

6 Stated Preference Analysis

6.1 Introduction

This chapter presents the findings of the stated preference surveys that were carried out amongst two target groups in 2012 and 2013. The two target groups were tourists and the population in the study area, for the planned cycle route. The analysis in this chapter is based on the scenario section completed by the respondents to the survey, that was detailed in Chapter 4. The purpose of this analysis was to ascertain how explanatory variables such as travel time, weather and gradients (these variables in this chapter are called “Travel Time”, “Weather Dry” and “Slope Flat”), impact upon the choices made for the different standards of cycling facilities. This analysis is supplemented by further investigation relevant to the demographic variables of respondents, such as age, gender, and income, and the possible effects of these variables on their choices. From this, the willingness to pay of the different target groups, for the different standards of facilities can be quantified.

6.2 Methodology

As mentioned previously, the stated preference survey targeted two groups. Both groups received a survey containing three sections. Section 1 sought information on perceptions and attitudes; however, the questions posed differed for the two target groups. Section 2 contained scenarios with various options. The tourists were asked to choose an option from the given scenario in the context of a sightseeing trip between two locations in the country. The study population were presented with a scenario, but were asked to make the choice twice. The first choice was in the context of a commute trip, and the second choice was in the context of a recreational trip. Please see section 4.2 to 4.9 of Chapter 4 for more details on the survey design, layout and sampling method.

6.2.1 Data Collection

As described in Chapter 4, the data for the scenarios was collected in 2012 and 2013 by means of intercept surveys and Internet based surveys. In total there were 1,132 valid responses from the two target groups. The sources and the numbers retrieved can be seen in Table 6-1.

Table 6-1 Survey Sources and the Responses

Survey Source	Responses
Intercept Survey of Tourists	287
National University of Ireland Survey	661
Intel Ireland Survey	57
Hewlett Packard Survey	46
Kilcock Business Association Survey	81
Total	1,132

6.3 Tourist Survey Analysis

As previously mentioned, the respondents were presented with four different scenarios, containing three options of cycling facilities, with varying conditions attached. Each respondent provided four answers, hence the total number of responses to this section is 1,148 (4 x 287), instead of a total of 287 (See section 4.4.6 for more details). It can be seen that the “Option C - Segregated from Traffic Cycling Facility” is very much preferred by tourists for cycling upon. The majority of respondents would be willing to sacrifice travel time and comfort (steeper gradients and persevere through inclement weather), in order to be fully separated from motorised traffic, than to cycle along a road with either no cycle infrastructure or a road with cycle lanes. The relationship between facility chosen and “Travel Time, “Weather Dry”, and “Slope Flat” is further developed in Section 6.3.1.

6.3.1 Tourist Stated Preference Analysis

As seen in Chapter 5, the choices for the scenarios are known, along with the conditions attached to each scenario. This data is inputted into NLogit along with the utility functions from Equations 4-11, 4-12 and 4-13 that were specified in Section 4.6.1 of Chapter 4. Multinomial Logit analysis was performed on the data and functions, and resulted in Table 6-2. NLogit estimates the coefficients for the constants and variables.

The results in Table 6-2 show that all the estimates had good significance (significance at a 1% and 5% level) with the exception of the weather parameter for "Option A – Road without Cycling Facilities". Significance is an indication of the probability that the coefficient estimated in the model is not correct (significance is explained in Section 4.10 of Chapter 4). This could be due to people choosing a road without cycling facilities, only if travel time is an issue, and weather was not found to be an overly influential factor. The coefficients are the beta value estimates for the utility function. The standard error is the standard deviation for the estimates. The Z score is the number of standard deviations by which the estimates for the coefficients differ from the mean. "|z|>Z*" indicates the statistical significance of the coefficients estimated. For more information on interpreting these parameter estimates please see Section 3.10 of Chapter 4 where the measuring for the performance of these models is explained in more detail. From investigating other studies, the author believes that the statistical significance of all the variables of the model in Table 6-2 is very good.

The results from Table 6-2 make intuitive sense with all the beta coefficients being negative for travel time, and positive for both weather and slope. This implies that for all options, as travel time increases for an option, respondents are less likely to choose that option. The more flat the route and the better the weather is for an option, the more likely that respondent will choose that facility. The log-likelihood value for this model is -721.04. The model tested is better than a constants only model, as the log-likelihood value for a constants only model was -803.44 (a lower log-likelihood than the constants only model is desired). A constants only model is a model that does not have any variables in the estimation, just constants. These models are estimated automatically by NLogit when estimating a model. The constants only model is used to identify if a model with constants and variables under investigation, is better than a simple constants only model. If the log-likelihood of the model with variables is more than the log-likelihood of the constants only model, then the model with variables and constants is not a good model and a model with just constants would be better. The pseudo R-squared for the analysis is reported with the model and was noted for the model estimated. However, it is imperative to note that this is not a typical R-squared[1] that is used in simple regression analysis. The R-squared estimated

[1] pseudo R-squared is a coefficient of determination that indicates how well the regression model fits to the data set under investigation

in NLogit is the pseudo R-squared value, and should only be used when comparing different models estimated from the same dataset, and not used in the comparison of models from other datasets (Bruin, 2006). The pseudo R-squared in NLogit are not indicative of the fit of a model, in relation to the data. The pseudo R-squared value for the model in Table 6-2 was 0.10. This value can then be used to compare other models estimated from the tourist dataset. The AICc[2] is the measure of the relative quality of the model. The AICc for this model is 1,464.10. The size and scale of an AICc on its own is not important in evaluating the appropriateness of a model. AICc is important when two different models have been created from the same dataset. The AICc can then be used to compare other models tested on this dataset, and used in determining the best model tested. Log likelihood, pseudo R-squared, and AICc is explained in more detail in Section 4.10 of Chapter 4.

From Table 6-2, it can be seen that when all else is held equal, the travel time variables for Option A (-0.03) is approximately half of the travel time variable for Option C (-0.05). This implies that a tourist would be willing to increase their travel time taken by approximately 100%, in order to travel upon a segregated from traffic cycling facility, rather than upon a road without any cycling infrastructure. The travel time variable for Option A is approximately 60% of the travel time variable for Option B. This implies that a tourist would be willing to increase their travel time by approximately 66%, in order to travel along a road with a cycle lane, rather than upon a road without any cycling infrastructure.

It can be seen how weather impacts upon choices made. Dry Weather has the biggest impact on Option B, and this is followed by Option C. This implies that dry weather would be a strong deciding factor in the decision of a respondent to choose Option B, whereas dry weather would seemingly not be an overly controlling factor when choosing Option C. This is most likely due to tourists willing to persevere through inclement weather (sacrifice some comfort), in order to travel upon the segregated from traffic cycling facility. The "Weather Dry" variable is lowest for Option A, implying that when the weather is dry and all else is held equal, tourists are least likely to choose Option A. This infers that tourists would mostly

[2] Akaike Information Criterion coefficient is the measure of the relative quality of the statistical model for a given set of data. This criterion provides a means for model selection and comparison by trading off of the complexity and the goodness to fit of the model

select a road without cycling infrastructure when travel time and the route gradient are the main issues.

The "Slope Flat" parameter estimates are approximately equal for the three options. The parameter estimates vary by approximately 5% for the options. The parameter estimate declines from 0.71 for Option A, to 0.69 for Option B, to 0.67 for option C. The decline is very slight, but one can surmise that tourists are tolerant of a slightly steeper route gradient, for better quality cycling infrastructure. However, as the changes between the parameters are minor, tourists may be quite sensitive to varying gradients. A steep route gradient would most likely deter a tourist from choosing a segregated cycling facility, and instead a tourist would choose another option.

Table 6-2 Estimates for the most basic tourism model

Estimate	**Coefficient**	**Standard Error**	**z**	**|z|>Z***
Option A – Road without cycling facilities				
Constant	-2.95***	0.36	-8.14	0.00
Travel Time	-0.03**	0.01	-2.21	0.03
Weather Dry	0.22	0.24	0.91	0.36
Slope Flat	0.71***	0.26	2.72	0.01
Option B – Road with Cycling facilities				
Constant	-2.08***	0.29	-7.24	0.00
Travel Time	-0.04***	0.01	-4.73	0.00
Weather Dry	0.87***	0.18	4.90	0.00
Slope Flat	0.69***	0.18	3.97	0.00
Option C – Segregated from Traffic Cycling Facility				
Travel Time	-0.05***	0.01	-8.23	0.00
Weather Dry	0.56***	0.15	3.77	0.00
Slope Flat	0.67***	0.15	4.50	0.00
Sample	**1,148**			
Pseudo R-squared	**0.10**			
Log-likelihood	**-721.04**			
AICc	**1,464.10**			

*** Significant at a 1% level
** Significant at a 5% level
* Significant at 10% level

Cost coefficients have been estimated from the travel time parameter estimates in Table 6-3. These coefficients were derived from Equation 4-22. The process for this is explained in Section 4.8.1 of Chapter 4. The ratios of the coefficients from Option A to Option B and Option C were then calculated. It can be seen in Table 6-3 how the cost ratio between

Option A and B is 1.43. It can be deduced from this ratio that if there was a tangible cost for the three user facilities (a toll for instance), a tourist would be willing to pay 43% more for a cycle lane than for a road without any cycling facilities. Similarly, a tourist would be willing to pay 91% more, for a fully segregated from vehicular traffic cycling facility. The value of time is taken to be €10.98 an hour from the National Roads Authority (2011). As discussed in Section 3.8.2 of Chapter 4, this value of time was used as there is no alternative value of cycling time in Ireland. The travel time parameter estimates were estimated in minutes, therefore the value of time was altered to €0.18 a minute. The cost per minute of each option was calculated, and the differences between Option A, and Option B and Option C were worked out. It can be seen in Table 6-3 how a tourist would be willing to pay €0.08 per minute to travel upon a cycle lane along a road, rather than a road without any cycling infrastructure. A tourist would be willing to pay €0.16 per minute to travel along a segregated from traffic cycling facility, over a road without any cycling infrastructure.

Table 6-3 Cost Coefficients Estimates from the Travel Time Parameter Estimates and the Willingness to Pay of Tourists for Different Cycling Facilities for the Basic Tourist Model

Estimate	**Coefficent**
Option A – Road without cycling facilities – Cost	-0.02
Option B – Road with Cycling facilities – Cost	-0.02
Option C – Segregated from Traffic Cycling Facility – Cost	-0.03
Ratio of Option A to the other options	
Option A – Road without cycling facilities – Cost	1
Option B – Road with Cycling facilities – Cost	1.43
Option C – Segregated from Traffic Cycling Facility – Cost	1.91
Cost of each Option per minute (€/min)	
Option A – Road without cycling facilities – Cost	€0.18
Option B – Road with Cycling facilities – Cost	€0.26
Option C – Segregated from Traffic Cycling Facility – Cost	€0.34
Willingness to Pay (€/min)	
Extra amount that a tourist would be willing to pay for Option B over Option A	€0.08
Extra amount that a tourist would be willing to pay for Option C over Option A	€0.16

Many extensions of the basic tourism model were completed. All the demographic variables that were collected from the survey were added individually to the basic model. A collection of other variables based on the tourists perceptions of cycling from the survey were also added to the survey. Each time a new model was evaluated, the significance of the variables, pseudo R-squared, log-likelihood and AICc were noted. Following this, various combinations of the variables with the basic model were then tested. The resulting details of significance, AICc, etc, were again noted. It started to become apparent which variables delivered the best blend of significance of variables within the model, and improved pseudo R-squared, log-likelihood, and AICc and produced the best model. These blends were repeatedly mixed and retested, eventually eliminating different variables depending on the performance.

During the various iterations of these extended models it was also important to limit the variables to those that were pertinent to real life situations. This was to keep the analysis relevant whilst also maintaining the significance level of the variables and the overall quality of the model. It was also crucial to use variables that would not be correlated with each other, as this would lead collinearity in the regression, which causes computational problems in the analysis. This would be detrimental to the model, therefore correlation should be avoided.

It was found that the model in Table 6-4 presented the best combination of estimates that were significant, and a model that improved the pseudo R-squared and the log-Likelihood of the basic model. The log-likelihood for a constants only model was again -803.45 and the log-likelihood for the model in Table 6-4 was -699.00. The log likelihood for the basic tourist model in Table 6-2 was -721.04. This indicates that the extended tourist model in Table 6-4 is a better model than the basic model in Table 6-2. The pseudo R-squared improves from 0.10 to 0.13 for the extended model. The AICc for this improved model is 1,444.00. One wants to reduce the AICc for models, therefore the AICc of the more complex model is better than the basic model's AICc of 1,464.10. The improved log-likelihood, pseudo R-squared and AICc show that this model improves on the original model.

The "Age" variable was the age of the respondents to the survey. This was numerically categorised with 1 representing the 12 – 24 year old age group, and rising to 6 representing the 65+ years of age group. The "Gender" variable represents the gender of the respondents, with 0 being male and 1 being female. The "Income" variable represented the household income of the respondents, which was split into five numerically coded categories, with the lower numbers representing a lower income, and the higher numbers representing higher incomes. The “Bikes Owned” variable represented the number of bikes owned within the household of the respondent. This variable was again numerically coded into five categories, with the lower numbers representing a lower quantity of bikes owned and the higher number a higher number of bikes owned. The categories of the relevant variables and their codes used for the analysis can be viewed in Table 6-4.

Table 6-4 Variables and the Associated Categories

Variable	Definition
Age	
Respondent Age: 12 – 24 Years	= 1 if the Respondents is 12 – 24 years old
Respondent Age: 25 – 34 Years	= 2 if the Respondents is 25 – 34 years old
Respondent Age: 35 – 44 Years	= 3 if the Respondents is 35 – 44 years old
Respondent Age: 45 – 54 Years	= 4 if the Respondents is 45 – 54 years old
Respondent Age: 55 – 64 Years	= 5 if the Respondents is 55 – 64 years old
Respondent Age: 65 +Years	= 6 if the Respondents is 65 + years old
Gender	
Gender: Male	(Reference Category = Gender: male)
Gender: Female	= 1 if the Respondent is Female
Income	
Household Income: Less than €9,999	= 1 if the Household Income: Less than €9,999
Household Income: €10,000 - €40,000	= 2 if the Household Income: €10,000 - €40,000
Household Income: €40,001 - €70,000	= 3 if the Household Income: €40,001 - €70,000
Household Income: €70,001 - €100,000	= 4 if the Household Income: €70,001 - €100,000
Household Income: €100,001 +	= 5 if the Household Income: €100,001 +
Bikes Owned	
Bikes Owned: None	= 1 if the Bikes in Household: None
Bikes Owned: One	= 2 if the Bikes in Household: One
Bikes Owned: Two	= 3 if the Bikes in Household: Two
Bikes Owned: Three or more	= 4 if the Bikes in Household: Three or more

The significance for some of the estimated parameter estimates was less than 0.05. “Weather Dry” and Income for Option A was not significant. For Option B, “Age”, “Gender”, and “Bikes Owned” were not significant, and for Option C, “Gender” and “Bikes Owned” were not significant. Even though there were some variables that were not significant in the estimation of the final extended model, it was determined that the final model proved to be better with the non-significant variables included rather than when they were excluded (better log-likelihood, pseudo R-squared, AICc, and significance of other variables). There was a loss of significance for many of the other variables, along with a decrease in pseudo R-squared, AICc, and Log likelihood, when the variables that were not originally significant were omitted.

From Table 6-5, it can be seen that the coefficients for the constants, “Travel Time”, “Weather Dry” and “Slope Flat” have remained approximately the same without the coefficient altering by more than 10%, compared to those presented in Table 6-2. The significance for these parameter estimates has remained the same also, except for “Slope Flat” for Option A which reduced, but not to a level that it was no longer significant at a 5% level. So, the relationships for “Travel Time”, “Weather Dry”, and “Slope Flat” have remained approximately the same as before. However, one can now see how the respondents’ personal demographic information affects the choices made. Therefore, for both models when all else is held equal, tourists are willing to increase their travel time by approximately 100%, in order to pass along a segregated from traffic cycle facility, and approximately 40% to travel upon a road with a cycle lane. For both models, “Weather Dry” had the biggest impact on Option B, followed by Option C and then Option A. However, “Weather Dry” for Option A was much lower than the other options, indicating that Option A would be very unlikely to be selected when the weather is dry. For “Slope Flat”, the parameter estimates remained approximately the same, with only “Slope Flat” for Option A changing the most at 10%. This change of 10% indicates that the gradient for Option A, is not as important as it is for Options B and C. One can surmise from this that respondents who select Options B and C are tolerable of gradient in return for some form of cycling infrastructure.

“Age” is negative for Option A, implying that it is more likely that a tourist within a lower age group would choose a road without cycling infrastructure. The “Age” parameter estimate is positive for both Option B and Option C, implying that tourists in a higher age group would be more likely to choose these facilities. The “Age” parameter estimate is larger for Option C than for B, suggesting that more mature tourists would select Option C over Option B. The “Gender” parameter estimate for Option A is negative and quite large in scale relative to the “Gender” parameter estimates for Option B and C, implying that many more male tourists would be willing to select a road without cycling infrastructure, than female. The “Gender” parameter estimates for Option B and C are positive, suggesting that females are more likely to select these options, in preference to a road without any cycling infrastructure. The “Gender” parameter estimate is slightly larger for Option B than for Option C, suggesting that once some form of cycling infrastructure is present, a female tourist will select this option, and whether it is segregated from traffic or not is not overly influential. This is most likely related to the well documented known need for cycling infrastructure, to encourage more females to cycle.

The parameter estimate for “Income” for Option A was lowest out of all of the options. It has been well documented that a person’s level of income affects their decision to cycle or not. However, this varies from country to country. In the America’s it has been found that those with lower income levels were more likely to cycle than those with higher levels of income. However, in Europe it is opposite to the America’s. It is widely documented that those with higher levels of income are more likely to cycle, than those with lower levels in Europe (Witlox and Tindemans (2004), Plaut (2005), Guo et al (2007) and Parkin et al (2008)). The responses from the tourists in the dataset under investigation were from all over the World; therefore the mixture of propensity to cycle based on income is most likely affecting the choices. The “Income” parameter estimate for Option B was positive and implies that those with a higher income would choose Option B rather than Option A. However, for Option C the “Income” parameter estimate was negative and implies that those with a lower income would be more likely to choose Option C over Option B. This may be due to those with a higher income having a greater value of time, and therefore place more emphasis on time, and are more likely to choose Option A if the travel time is shorter.

The “Bikes Owned” parameter estimates indicate that the higher the number of bicycles within the tourist’s household, the more likely that the tourist will select option A, and the lower the number of bikes in the tourist’s household, the more likely they are to select Option C. It can be seen in Table 6-5 that the “Bikes Owned” parameter estimate for Option A is positive, whereas the “Bikes Owned” parameter estimate for the Options B and C are negative. This is most probably due to a higher ownership of bikes within a tourist’s household, implying a greater likelihood of their cycling in their own country of residence. Therefore, the tourist would be more confident in cycling and not as nervous about cycling among traffic, as a tourist who would not have access to a bike in their country of residence. The negative parameter estimate is larger for Option C than Option B indicating that if a person has either no bikes or very few bikes in their household, they are more likely to choose Option C.

Table 6-5 Basic Tourism Model including Age, Gender, Income and Bicycle Owned

Estimate	Coefficient	Standard Error	Z	|z|>Z*
Option A – Road without cycling facilities				
Constant	-2.21***	0.67	-3.32	0.00
Travel Time	-0.03**	0.01	-2.08	0.04
Weather Dry	0.26	0.25	1.05	0.29
Slope Flat	0.62**	0.27	2.32	0.02
Age	-0.24***	0.10	-2.58	0.01
Gender	-0.64***	0.23	-2.73	0.01
Income	0.07	0.09	0.81	0.42
Bikes Owned	0.35***	0.11	3.06	0.00
Option B – Road with Cycling facilities				
Constant	-2.44***	0.53	-4.64	0.00
Travel Time	-0.04***	0.01	-4.68	0.00
Weather Dry	0.84***	0.18	4.74	0.00
Slope Flat	0.71***	0.18	3.99	0.00
Age	0.06	0.05	1.10	0.27
Gender	0.20	0.17	1.17	0.24
Income	0.12**	0.05	2.15	0.03
Bikes Owned	-0.05	0.07	-0.68	0.50
Option C – Segregated from Traffic Cycling Facility				
Travel Time	-0.05***	0.01	-8.11	0.00
Weather Dry	0.58***	0.15	3.84	0.00
Slope Flat	0.70***	0.15	4.58	0.00
Age	0.08*	0.05	1.71	0.09
Gender	0.13	0.15	0.87	0.39
Income	-0.15***	0.05	-2.99	0.00
Bikes Owned	-0.07	0.07	-1.09	0.28
Sample	**1,148**			
Pseudo R-squared	**0.13**			
Log-likelihood	**-699.00**			
AICc	**1,444.00**			

*** Significant at a 1% level
** Significant at a 5% level
* Significant at 10% level

The cost coefficients are recalculated with the new travel time parameter estimates in the same fashion as they were for Table 6-3 and can be seen in Table 6-6. The ratios were again computed and then calculated with the value of time. It can be seen in Table 6-6 that the ratio for Option B is 1.48. This indicates that if there was a tangible cost for using the cycling facilities, a tourist would be willing to pay 48% more for a road with a cycle lane, than a road without a cycle lane, all else being held equal. The ratio for Option C is 1.98 indicating that a tourist would be willing to pay 98% more for a segregated from traffic cycling facility, than for a road without any cycling facilities. Even though the "Travel Time" parameter estimates only changed slightly in the second model, the willingness of a tourist to pay for a road with a cycle lane, increased from €0.08 per minute to €0.22 per minute, and for a fully segregated from traffic cycle facility, the willingness to pay increased from €0.16 per minute to €0.19 per minute.

Table 6-6 Cost Coefficients Estimates from the Travel Time Parameter Estimates and the Willingness to Pay of Tourists for Different Cycling Facilities for the Extended Tourist Model

Estimate	**Coefficient**
Option A - Road without cycling facilities – Cost	-0.05
Option B - Road with Cycling facilities – Cost	-0.08
Option C - Segregated from Traffic Cycling Facility – Cost	-0.11
Ratio of Option A to the other options	
Option A - Road without cycling facilities – Cost	1
Option B - Road with Cycling facilities – Cost	1.48
Option C - Segregated from Traffic Cycling Facility – Cost	1.98
Cost of each Option per minute (€/min)	
Option A - Road without cycling facilities – Cost	€0.18
Option B - Road with Cycling facilities – Cost	€0.27
Option C - Segregated from Traffic Cycling Facility – Cost	€0.37
Willingness to Pay (€/min)	
Extra amount that a tourist would be willing to pay for Option B over Option A	€0.09
Extra amount that a tourist would be willing to pay for Option C over Option A	€0.19

From comparing the significances, pseudo R-squared, AICc, and the log-likelihood, it can be seen that the second model (the model containing the demographic information of age, gender, income and bicycles in household) is the better model. This model improves the pseudo R-squared, the log-likelihood, and has a better AICc than the basic model, whilst maintaining the significance of many variables. The extra demographic explanatory variables are also a valuable addition to the model. This is the model and the values that the author would recommend be used by anyone conducting research into the relationship between tourism and cycling.

6.3.2 Tourism Analysis Conclusions

From the results in this section, it was observed that tourists, when presented with either a road without cycle lanes, a road with cycle lanes, and a segregated from traffic cycling facility, with all other conditions being equal, the tourist will select the segregated facility approximately 75% of the time, the road with cycle lanes 18% of the time, and the road without any cycling facilities 7% of the time. From the regression analysis performed on this data the following is now known:

- A tourist is willing to increase their cycling travel time by approximately 100% in order to cycle upon a cycling facility which is fully segregated from traffic rather than along a road without cycling infrastructure, and are willing to increase their travel time by 40-50% to be able to cycle along a road with a cycle lane, rather than a road without cycling facilities.
- Younger, male tourists, who own one or more bikes are more likely to choose a road without cycling facilities, while older, female tourists, who do not own any bikes, are more likely to choose a road with cycle lanes or a segregated from traffic cycling facility.
- Female tourists are very unlikely to select to use a road without any cycling facilities, however, once there is some form of cycling infrastructure a female tourist will be satisfied, be it segregated from traffic or not. Segregation from traffic was not highly influential for females.
- If there was a tangible cost to using a cycling facility, a tourist would be willing to pay 48% more for a road with cycle lanes, than for a road without cycling facilities and 98% more for a cycling facility which is fully segregated from traffic, than for a road without cycling facilities.
- Using a value of time of €10.98 an hour or €0.18 per minute, it can be deduced that a cyclist is willing to pay €0.09 per minute for a road with a cycle lane, and €0.19 per minute for a cycling facility which is fully segregated from traffic.

6.4 Recreational and Commuter Survey Results

This section of the thesis looks at the results from the surveys undertaken in the study area. A detailed discussion of the target area can be found in Chapter 1. In total there were 845 responses.

The respondents were presented with four different scenarios, containing three cycling facilities with varying conditions attached. In Table 6-7, a summary of the choices of the respondents can be seen. The respondent was firstly asked to make a choice in the given scenario for a commute trip to and from their place of work or education. The respondents were then asked to make the choice again, except in the context of a recreational trip. Each respondent provided eight answers, four responses for the commute trip and four responses for the recreational trip. Therefore, the total number of responses is 3,380 (845 x 4) for both the commute and recreational choices, instead of 845. It can be seen that the "Option C - Segregated from Traffic Cycling Facility" is very much preferred for both the commute trip and the recreational trip for cycling upon. A considerable proportion of respondents would be willing to sacrifice travel time and comfort (steeper gradients and persevere through inclement weather), in order to be fully separated from motorised traffic, than to cycle along a road with either no cycle infrastructure or a road with cycle lanes. The relationship between facility chosen and "Travel Time", "Weather Dry", and "Slope Flat" is further developed in the Section 6.5 and Section 6.6 of this chapter. Table 6-7 outlines the numbers and percentage from the scenarios section.

Table 6-7 Results from Section 2 - Scenarios

Facilities Chosen	Numbers	Percentage
Recreational Trip		
Option A - Road without cycling facilities	353	10
Option B - Road with Cycling facilities	544	16
Option C - Segregated from Traffic Cycling Facility	1779	53
No response	704	21
Total	3,380	100
Commute Trip		
Option A - Road without cycling facilities	349	10
Option B - Road with Cycling facilities	728	22
Option C - Segregated from Traffic Cycling Facility	1,599	47
No response	704	21
Total	3,380	100

6.5 Recreational Stated Preference Analysis

As seen in Table 6-7, the choices for the recreational scenarios are known, along with the conditions attached to each scenario. This data is inputted into NLogit along with the utility functions from Equations 4-11, 4-12 and 4-13 from section 4.6.1 in Chapter 4. Multinomial logit analysis was performed on the data and functions, and resulted in Table 6-8. NLogit estimates the coefficients for the constants and variables.

The results in Table 6-8 show that all the estimates had good significance (significance at a 1% and 5% level) with the exception of the travel time parameter for "Option A – Road without Cycling Facilities". However, this parameter was significant at a 10% level (significant at a 7% level, so just marginally outside the cut off for significance at a 5% level). This could be due to the variables "Slope Flat" and "Weather Dry", affecting the choice of a road without cycling facilities most, and travel time not being an overly important for recreational trips.

The results from Table 6-8 make intuitive sense with all the beta coefficients being negative for "Travel Time", and positive for both "Weather Dry" and "Slope Flat". This implies that for all options, as travel time increases for an option, respondents are less likely to choose that option. The more flat, and the better the weather is for an option, the more likely that respondent will choose that facility. The log-likelihood value for this model is -2,228.63. The model tested is better than a constants only model, as the log-likelihood value for a constants only model is -2,304.75 (a lower log-likelihood than the constants only model is desired). The pseudo R-squared value for the model in Table 6-8 is 0.03. The AICc for this model is 1,464.10 (when comparing with other models a lower AICc is desired). These values will be used in the comparison of other models based on the recreational dataset.

From Table 6-8, it can be seen that when all else is held equal, the travel time parameter estimates for Option A (-0.01) is approximately one third of the travel time parameter estimate for Option C (-0.02). This implies that a recreational cyclist would be willing to increase their travel time by approximately 200% in order to travel upon a segregated from traffic cycling facility, rather than upon a road without any cycling infrastructure. The "Travel Time" parameter estimate for Option A is approximately 65% of the "Travel Time" parameter estimate for Option B. This implies that a recreational cyclist would be willing to increase their travel time approximately 53%, in order to travel along a road with a cycle lane, rather than upon a road without any cycling infrastructure.

It can be seen how "Weather Dry" has the biggest impact on Option B, and this is followed by Option C. This implies that dry weather would be mostly the reason why a respondent would choose Option B, whereas dry weather would seemingly not be a strong influential factor when choosing Option A. This is most likely due to recreational cyclists willing to persevere through inclement weather (sacrifice some comfort) in order to travel upon some form of cycle infrastructure. The low “Weather Dry” parameter estimate for Option A implies that recreational cyclists would mostly select a road without cycling infrastructure, when travel time and the route gradient are the main issues.

From the analysis, there is evidence of an approximately linear relationship between the standard of cycling facilities and route gradient for recreational cyclists. The parameter estimates increase with the perceived quality of the cycling facility, however, this relationship tapers for the higher quality facilities, as the estimate for Option B is only slightly smaller than Option C. This implies that recreational cyclists are willing to tolerate gradients, in order to have some form of cycling infrastructure. The estimates for Option B and Option C imply recreational cyclists are quite sensitive to gradient and will switch between Option B and Option C, if one has a steeper gradient than the other. A recreational cyclist may be more likely to choose Option B over Option C, if Option C has some gradients and Option B has no gradients.

Table 6-8 Estimates for the Most Basic Recreational Model

Estimate	**Coefficient**	**Standard Error**	**z**	**|z|>Z***
Option A - Road without cycling facilities				
Constant	-1.84***	0.16	-10.91	0.00
Travel Time	-0.01*	0.01	-1.84	0.07
Weather Dry	0.27**	0.12	2.34	0.02
Slope Flat	0.23**	0.12	2.00	0.05
Option B - Road with Cycling facilities				
Constant	-1.63***	0.16	-10.48	0.00
Travel Time	-0.01***	0.00	-2.86	0.00
Weather Dry	0.72***	0.10	4.90	0.00
Slope Flat	0.30***	0.10	3.02	0.00
Option C - Segregated from Traffic Cycling Facility				
Travel Time	-0.02***	0.00	-6.90	0.00
Weather Dry	0.40***	0.08	4.70	0.00
Slope Flat	0.31***	0.09	3.69	0.00
Sample	**2,668**			
Pseudo R-squared	**0.03**			
Log-likelihood	**-2,228.63**			
AICc	**4,479.30**			

*** Significant at a 1% level

** Significant at a 5% level
* Significant at 10% level

The cost coefficients and ratios have been estimated from the "Travel Time" parameter estimates in Table 6-8. These coefficients were derived in a similar manner to Table 6-8. It can be seen in Table 6-9 how the cost ratio between Option A and B is 1.32. It can be deduced from this ratio, that a recreational cyclist would be willing to pay 32% more for a cycle lane, than for a road without any cycling facilities. Similarly, a recreational cyclist would be willing to pay 157% more for a fully segregated from vehicular traffic cycling facility. The cost per minute of each option was calculated and the differences between Option A, and Option B and Option C were calculated. It can be seen in Table 6-9 how a recreational cyclist would be willing to pay €0.06 per minute to travel upon a cycle lane along a road, rather than a road without any cycling infrastructure. A recreational cyclist would be willing to pay €0.28 per minute to travel along a segregated from traffic cycling facility, over a road without any cycling infrastructure.

Table 6-9 Cost Coefficients Estimates from the Travel Time Parameter Estimates and the Willingness to Pay of Recreational Cyclists for Different Cycling Facilities for the Basic Recreational Model

Estimate	**Coefficent**
Option A - Road without cycling facilities – Cost	-0.02
Option B - Road with Cycling facilities – Cost	-0.03
Option C - Segregated from Traffic Cycling Facility – Cost	-0.05
Ratio of Option A to the other options	
Option A - Road without cycling facilities – Cost	1
Option B - Road with Cycling facilities – Cost	1.32
Option C - Segregated from Traffic Cycling Facility – Cost	2.57
Cost of each Option per minute (€/min)	
Option A - Road without cycling facilities – Cost	€0.18
Option B - Road with Cycling facilities – Cost	€0.24
Option C - Segregated from Traffic Cycling Facility – Cost	€0.46
Willingness to Pay (€/min)	
Extra that a recreational cyclist would be willing to pay for Option B over Option A	€0.06
Extra that a recreational cyclist would be willing to pay for Option C over Option A	€0.28

As in the Section 6.4, many extensions of the basic recreational model were completed. Keeping the model similar to the previously extended tourism model was also a factor to consider, in order for a comprehensive comparison completed between the models. It was found that the variables tested in the tourism model offered one of the best solutions for an extended model in this instance, except for the “Bikes Owned” variable. This was not significant in any of the potential models tested, and it was found that when “Bikes Owned” was replaced by the “Single” variable, there was significance and the fit of the model improved. Having similar models allowed for the altering of the relationships of the variables to be observed between the two groups, and analysis of how these relationships change between groups to be completed.

Table 6-11 presents the extension of the basic recreational model. The extension contains the variables “Travel Time”, “Weather Dry” and “Slope Flat” from the basic model, and these are combined with the variables “Age”, “Gender”, “Income” and “Single” (variable representing relationship status). These variables were coded in a similar fashion to the tourist model in Section 6.4, with exception of “Bikes Owned” being replaced by “Single”. The manner in which the variables were coded can be viewed in Table 6-10.

These estimates improve upon the original basic model, as the majority of the variables estimated have good significance, and the model estimated has improved upon the pseudo R-squared, log-likelihood, and the AICc of the basic recreational model. The log-likelihood for the extended recreational model is 2,182.87. This improves upon the log-likelihood of the basic model of 2,228.63. The pseudo R-squared for the extended recreational model is 0.05. This improves upon the original pseudo R-squared for the basic recreational mode of 0.03. The AICc for the extended recreational model is 4,399.70. This compares favourably to the AICc of the original basic recreational model of 4,479.30. These improvements indicate that the extended recreational model offers a better alternative to the basic recreational model.

As in the extended tourism model, the “Age” variable was the age of the respondents to the survey. This was numerically categorised with 1 representing the 12 – 24 year old age group, and rising to 6 representing the 65+ years of age group. The “Gender” variable represents the gender of the respondents, with 0 being male and 1 being female. The “Income” variable represented the household income of the respondents, which was split into five numerically coded categories, with the lower numbers representing a lower income and the higher numbers representing higher incomes. The “Single” variable represented the relationship status of the respondent. This variable was again numerically coded with 1 representing a respondent that was single and 0 representing a respondent that was not single.

Table 6-10 Variables and the Associated Categories with Bikes Owned Replaced by Single

Variable	Definition
Age	
Respondent Age: 12 – 24 Years	= 1 if the Respondents is 12 – 24 years old
Respondent Age: 25 – 34 Years	= 2 if the Respondents is 25 – 34 years old
Respondent Age: 35 – 44 Years	= 3 if the Respondents is 35 – 44 years old
Respondent Age: 45 – 54 Years	= 4 if the Respondents is 45 – 54 years old
Respondent Age: 55 – 64 Years	= 5 if the Respondents is 55 – 64 years old
Respondent Age: 65 +Years	= 6 if the Respondents is 65 + years old
Gender	
Gender: Male	(Reference Category = Gender: male)
Gender: Female	= 1 if the Respondent is Female
Income	
Household Income: Less than €9,999	= 1 if the Household Income: Less than €9,999
Household Income: €10,000 - €40,000	= 2 if the Household Income: €10,000 - €40,000
Household Income: €40,001 - €70,000	= 3 if the Household Income: €40,001 - €70,000
Household Income: €70,001 - €100,000	= 4 if the Household Income: €70,001 - €100,000
Household Income: €100,001 +	= 5 if the Household Income: €100,001 +
Single	
Relationship Status: Single	= 1 if the Relationship Status: Single
Relationship Status: Not Single	(Reference Category = Gender: Not Single)

The significance for some of the estimated coefficients was less than 0.05. Travel time for Option A was again not significant at a 1% or 5% level, however, it was marginally just outside significance at a 10% level. “Single” for Option A was also not significant at a 1% or 5% level; however, this too was just marginally outside significance at a 10% level. “Income” was not significant at a 1% or 5% level for Option B. All the other variables in the model were significant at a 1% or 5% level. Even though there were some variables that were not significant in the estimation of the final extended model, it was determined that the final model proved to be better with the non-significant variables included rather than when they were excluded (better log-likelihoods, pseudo R-squareds, AICc’s, and significance of other variables).

From Table 6-11, it can be seen that the coefficients for the constants, “Travel Time”, “Weather Dry” and “Slope Flat” have remained approximately the same, without the parameter estimate altering by more than 10%, except the constant Option A altered by approximately 20%. However, this does not have an overly large impact on the parameter estimates. The significance for these parameter estimates has also remained the same except for travel time for Option A which reduced, however the significance was only marginally outside significance at a 10% level. Therefore the relationships for “Travel Time”, “Weather Dry”, and “Slope Flat” have remained approximately the same as before; nevertheless, one can now see how the respondents’ personal demographic information affects the choices made. Therefore, for both models when all else is held equal, recreational cyclists are willing to increase their travel time by approximately 150% in order to pass along a segregated from traffic cycle facility, and approximately 30% to travel upon a road with a cycle lane. For both models, “Weather Dry” had the biggest impact on Option B, followed by Option C and then Option A. “Weather Dry” was not as an important issue for Option A as it was for the others, as it was much lower, indicating that if the weather is dry, recreational cyclists would be unlikely to choose Option A. For “Slope Flat”, the parameter estimates remained approximately the same, with “Slope Flat” for Option A remaining nearly identical, and changing by no more than 10% for Option B and Option C. One can surmise that respondents who select Option B and Option C are willing to tolerate gradients, in order to travel along some form of cycling infrastructure.

“Age” is positive for Option A, implying that it is more likely that a recreational cyclist with a higher age, would choose a road without cycling infrastructure. The “Age” parameter estimate is negative for Option B, implying that recreational cyclists would be younger in age when choosing this option. The “Gender” parameter estimate for Option A is negative, and quite large in scale relative to the negative “Gender” parameter estimate for Option B. This implies that many more male recreational cyclists than females would be willing to select a road without cycling infrastructure. More male recreational cyclists than females would be willing to choose Option B also, however, not on as large a scale as Option A. These parameter estimates imply that female recreational cyclists have a strong preference for Option C, with few choosing Option B, and even fewer choosing Option A. This most likely related to the well documented known need for cycling infrastructure to encourage females to cycle. The parameter estimate for “Income” for Option A was positive and relatively larger than the positive parameter estimate for Option B. This implies that those with higher incomes are willing to choose Option A over the other options. The “Income” parameter estimate for Option B was positive, and implies that those with a lower income would choose Option C rather than Option A or Option B. The “Single” parameter estimate for Option A and Option B are positive and relatively similar. This suggests that recreational cyclists that choose Option A and Option B are more likely to be single. From this, it can be inferred that those who are not single are more likely to choose Option C. This could be due to those being in a relationship having a partner and possibly children. Therefore, if they are cycling for recreational purposes, they are more likely to be cycling with their partner and/or their children, and therefore the safety of their partner and children is probably a factor. The parameter estimates for the variables discussed can be seen in Table 6-11.

Table 6-11 Basic Recreational Model including Age, Gender, Income and Bicycle Owned

Estimate	Coefficient	Standard Error	Z	|z|>Z*
Option A - Road without cycling facilities				
Constant	-2.22***	0.22	-10.04	0.00
Travel Time	-0.01	0.01	-1.61	0.10
Weather Dry	0.28**	0.12	2.32	0.02
Slope Flat	0.24**	0.12	1.99	0.05
Age	0.58***	0.15	3.86	0.00
Gender	-0.86***	0.13	-6.73	0.00
Income	0.12***	0.03	3.69	0.00
Single	0.20	0.14	1.44	0.15
Option B - Road with Cycling facilities				
Constant	-1.39***	0.19	-7.41	0.00
Travel Time	-0.01***	0.00	-2.95	0.00
Weather Dry	0.72***	0.10	7.06	0.00
Slope Flat	0.32***	0.10	3.18	0.02
Age	-0.34***	0.12	-3.28	0.00
Gender	-0.32***	0.10	-3.11	0.00
Income	0.01	0.03	0.45	0.65
Single	0.22**	0.11	2.02	0.04
Option C - Segregated from Traffic Cycling Facility				
Travel Time	-0.02***	0.00	-7.14	0.00
Weather Dry	0.43***	0.09	5.09	0.00
Slope Flat	0.33***	0.09	3.84	0.00
Sample	**3,380**			
Pseudo R-squared	**0.05**			
Log likelihood	**-2,182.87**			
AICc	**4,399.70**			

*** Significant at a 1% level
** Significant at a 5% level
* Significant at 10% level

The cost coefficients are recalculated with the new travel time parameter estimates in the same fashion as Table 6-9. The ratios were again computed and then calculated with the value of time. It can be seen in Table 6-12 that the ratio for Option B is 1.53. This indicates that if there was a tangible cost for using the cycling facilities, a recreational cyclist would be willing to pay 53% more for a road with a cycle lane, than a road without a cycle lane, all else being held equal. The cost ratio for Option C is 3.00 indicating that a recreational cyclist would be willing to pay 200% more for a segregated from traffic cycling facility, than for a road without any cycling facilities. Even though the “Travel Time” parameter estimates only changed slightly in the second model, the willingness of a recreational cyclist to pay for a road with a cycle lane, increased from €0.06 per minute to €0.10 per minute, and for a fully segregated from traffic cycle facility, the willingness to pay increased from €0.28 per minute to €0.36 per minute.

Table 6-12 Cost Coefficients Estimates from the Travel Time Parameter Estimate and the Willingness to Pay of Recreational Cyclists for Different Cycling Facilities for the Extended Recreational Model

Estimate	Coefficient
Option A - Road without cycling facilities – Cost	-0.02
Option B - Road with Cycling facilities – Cost	-0.03
Option C - Segregated from Traffic Cycling Facility – Cost	-0.5
Ratio of Option A to the other options	
Option A - Road without cycling facilities – Cost	1
Option B - Road with Cycling facilities – Cost	1.53
Option C - Segregated from Traffic Cycling Facility – Cost	3.00
Cost of each Option per minute (€/min)	
Option A - Road without cycling facilities – Cost	€0.18
Option B - Road with Cycling facilities – Cost	€0.28
Option C - Segregated from Traffic Cycling Facility – Cost	€0.54
Willingness to Pay (€/min)	
Extra that a recreational cyclist would be willing to pay for Option B over Option A	€0.10
Extra that a recreational cyclist would be willing to pay for Option C over Option A	€0.36

6.5.1 Recreational Analysis Conclusions

From the results in this section, it was observed that recreational cyclists, when presented with either a road without cycle lanes, a road with cycle lanes, and a segregated from traffic cycling facility, the recreational cyclist will select the segregated facility approximately 67% of the time, the road with cycle lanes 20% of the time, and the road without any cycling facilities 13% of the time. From the regression analysis performed on this data the following is now known:

- A recreational cyclist is willing to increase their cycling travel time by approximately 200% in order to cycle upon a cycling facility which is fully segregated from traffic, rather than along a road without cycling infrastructure, and are willing to increase their travel time by 32% to be able to cycle along a road with a cycle lane, rather than a road without cycling facilities.
- Older, single, male recreational cyclists, are more likely to choose a road without cycling facilities or a road with a cycle lane, while younger, female recreational cyclists,

who are in a relationship, are more likely to choose a road with a segregated from traffic cycling facility.

- Female recreational cyclists are very unlikely to select to use a road without any cycling facilities, and, are unlikely to select a road with cycle lanes. Female recreational cyclists have a strong desire to be segregated from traffic. Segregation from traffic was highly influential for females cycling for recreational purposes.
- If there was a tangible cost to using a route with cycling facilities, a recreational cyclist would be willing to pay 32% more for a road with cycle lanes, than for a road without cycling facilities and 200% more for a cycling facility which is fully segregated from traffic, than for a road without cycling facilities.
- Using a value of time of €10.98 an hour or €0.18 per minute, it can be deduced that a cyclist is willing to pay €0.10 per minute for a road with a cycle lane and €0.36 per minute for a cycling facility which is fully segregated from traffic.

6.6 Commuters Stated Preference Analysis

As seen in Chapter 5, the choices for the commute scenarios are known along with the conditions attached to each scenario. This data is inputted into NLogit along with the utility functions from Equations 4-11, 4-12 and 4-13 from section 4.6.1 in Chapter 4. Multinomial logit analysis was performed on the data and functions, and resulted in Table 6-13. NLogit estimates the coefficients for the constants and parameters.

The results in Table 6-13 show that all the estimates had good significance (significance at a 1% and 5% level) with the exception of the “Weather Dry” parameter for “Option A – Road without Cycling Facilities”. However, this parameter was significant at a 10% level. This could be due to the variables “Travel Time” and “Slope Flat”, affecting the choice of a road without cycling facilities most and weather not being an overly influential factor.

The results from Table 6-13 make intuitive sense with all the beta coefficients being negative for “Travel Time”, and positive for both “Weather Dry” “and “Slope Flat”. This implies that for all options, as travel time increases for an option, respondents are less likely to choose that option, and the more flat and the better the weather is for an option, the more likely that respondent will choose that facility. The log-likelihood value for this model is -2,250.49. Similarly to the models in Section 6.5 and Section 6.6, the model tested is better than a constants only model as the log-likelihood value for a constants only model is -2,477.87 (a lower log-likelihood than the constants only model is desired). The pseudo R-squared value for the model in Table 6-13 is 0.09. The AICc for this model is 4,523.00. These values will be used in the comparison of other models based on the commuter dataset.

From Table 6-13, it can be seen that when all else is held equal, the travel time parameter estimates for Option A (-0.02) is approximately half of the travel time parameter estimate for Option C (-0.05). This implies that a recreational cyclist would be willing to increase their travel time by approximately 100% in order to travel upon a segregated from traffic cycling facility, rather than upon a road without any cycling infrastructure. The travel time parameter estimate for Option A is approximately 60% of the travel time parameter estimate for Option B. This implies that a tourist would be willing to increase their travel time by approximately 90%, in order to travel along a road with a cycle lane, rather than upon a road without any cycling infrastructure.

It can be seen how dry weather has the biggest impact on Option B, and this is followed by Option C. This implies that dry weather would be the main reason why a commute cyclist would choose Option B, whereas dry weather would not be a strong influential factor for those choosing Option A. This is probably due to commute cyclists being willing to persevere through inclement weather (sacrifice some comfort) in order to travel upon some form of cycle infrastructure. The low “Weather Dry” parameter estimate for Option A relative to Option B and Option C implies that commute cyclists would mostly select a road without cycling infrastructure, when travel time and the route gradient are the main issues.

The parameter estimate for “Slope Flat” for Option B is larger than Option A and Option C. This implies that commute cyclists choosing Option B would mostly do so, when it has a very low gradient. “Slope Flat” is, relative to the other parameter estimates, low for Option A. This could be due to “Slope Flat” not being an overly influential variable for the decision to choose Option A. Travel time is most likely the reason a commuter would choose Option A, and the route gradient is only a minor factor. “Slope Flat” for Option C is lower than Option B implying that a slight increase in gradient would be tolerated by commuters, in order to be segregated from traffic. This relationship for “Slope Flat” could be due to some respondents not understanding the condition in relation to gradient. There could also be an issue in relation to the placement of the gradient condition. The gradient condition was the last condition presented to respondents in a scenario, so there may be some respondents who had already decided what option they would choose before reading the gradient condition. The gradient variable may also have been difficult for some of the respondents to put into context and there may have been some respondents who skipped the gradient condition. The parameter estimates for the discussed variables can be seen in Table 6-13.

Table 6-13 Estimates for the Most Basic Commute Model

Estimate	Coefficient	Standard Error	z	|z|>Z*
Option A - Road without cycling facilities				
Constant	-1.98***	0.18	-11.29	0.00
Travel Time	-0.02***	0.01	-4.26	0.00
Weather Dry	0.22*	0.12	1.82	0.07
Slope Flat	0.28**	0.12	2.30	0.02
Option B - Road with Cycling facilities				
Constant	-1.17***	0.15	-7.83	0.00
Travel Time	-0.05***	0.04	-10.19	0.00
Weather Dry	0.71***	0.10	7.50	0.00
Slope Flat	0.43***	0.10	4.48	0.00
Option C - Segregated from Traffic Cycling Facility				
Travel Time	-0.05***	0.00	-14.13	0.00
Weather Dry	0.43***	0.09	5.06	0.00
Slope Flat	0.36***	0.09	4.14	0.00
Sample	**3,384**			
Pseudo R-squared	**0.09**			
Log-likelihood	**-2,250.49**			
AICc	**4,523.00**			

*** Significant at a 1% level
** Significant at a 5% level
* Significant at 10% level

The cost coefficients and ratios have been estimated from the "Travel Time" parameter estimates in Table 6-14. These coefficients were derived in a similar manner to Table 6-13. It can be seen in Table 6-14 how the cost ratio between Option A and Option B is 1.92. It can be deduced from this ratio that a recreational cyclist would be willing to pay 92% more for a cycle lane, than for a road without any cycling facilities. Similarly, a recreational cyclist would be willing to pay 111% more for a fully segregated from vehicular traffic cycling facility. The cost per minute of each option was calculated, and the differences between Option A, and Option B and Option C were calculated. It can be seen in Table 6-14 how a commute cyclist would be willing to pay €0.17 per minute to travel upon a cycle lane along a road, in preference to a road without any cycling infrastructure. A commute cyclist would be willing to pay €0.20 per minute to travel along a segregated from traffic cycling facility, over a road without any cycling infrastructure.

Table 6-14 Cost Coefficients Estimates from the Travel Time Parameter Estimates and the Willingness to Pay of Commuter Cyclists for Different Cycling Facilities for the Basic Commuter Model

Estimate	**Coefficient**
Option A - Road without cycling facilities – Cost	-0.05
Option B - Road with Cycling facilities – Cost	-0.10
Option C - Segregated from Traffic Cycling Facility – Cost	-0.11
Ratio of Option A to the other options	
Option A - Road without cycling facilities – Cost	1
Option B - Road with Cycling facilities – Cost	1.92
Option C - Segregated from Traffic Cycling Facility – Cost	2.11
Cost of each Option per minute (€/min)	
Option A - Road without cycling facilities – Cost	€0.18
Option B - Road with Cycling facilities – Cost	€0.35
Option C - Segregated from Traffic Cycling Facility – Cost	€0.38
Willingness to Pay (€/min)	
Extra amount that a commuter would be willing to pay for Option B over Option A	€0.17
Extra amount that a commuter would be willing to pay for Option C over Option A	€0.20

As in the previous sections, many extensions of the basic recreational model were completed. Keeping the model similar to the previously extended tourism and recreational model was also an important factor to consider, in order for a comprehensive comparison to be made between all of the models. It was found that the variables tested in the tourism and recreational model again offered one of the best solutions for an extended model in this instance. The variables used in this extension were the same as the recreational model; therefore the “Bikes Owned” variable was omitted and replaced with the “Single” variable (relationship status). The “Bikes Owned” variable was again not significant for any option, and it was found that when “Bikes Owned” was replaced by the “Single” variable, there was significance and the fit of the model improved. This extension of the basic model proved to be the best for the commute analysis. This model offered the best combination of pseudo R-squared, significant variables, log-likelihood, and AICc. Having very similar models to the recreational and tourism models allowed similarities and contrasts to be observed.

Table 6-15 presents the extension of the basic commute model. The extension contains the original variables of “Travel Time”, “Weather Dry” and “Slope Flat”, and these are combined with “Age”, “Gender”, “Income” and “Single”. These variables were coded in the same manner as Table 6-12. These estimates improve upon the original basic model, as the majority of the variables estimated have good significance, and the model estimated has improved upon the pseudo R-squared, log-likelihood, and the AICc of the basic recreational model. The log-likelihood for the extended recreational model is 2,194.21. This improves upon the log-likelihood of the basic model of 2,250.49. The pseudo R-squared for the extended recreational model is 0.12. This improves upon the original pseudo R-squared for the basic recreational mode of 0.09. The AICc for the extended recreational model is 4,426.40. This compares favourably to the AICc of the original basic recreational model of 4,523.00. These improvements indicate that the extended commuter model offers a better alternative to the basic recreational model.

As in the tourism analysis and recreational model, the “Age” variable was the age of the respondents to the survey. This was numerically categorised with 1 representing the 12 – 24 year old age group, and rising to 6 representing the 65+ years of age group. The “Gender” variable represents the gender of the respondents, with 0 being male and 1 being female. The “Income” variable represented the household income of the respondents, which was split into five numerically coded categories, with the lower numbers representing a lower income, and the higher numbers representing higher incomes. The “Single” variable represented the relationship status of the respondent. This variable was again numerically coded with 1 representing a respondent that was single and 0 representing a respondent that was not single.

The variable “Single” for Option A, and “Gender” and “Income” for Option B were not significant at a 1% or 5% level. “Weather Dry” for Option A and “Age” for Option B were significant at a 10% level, and all the other variables were significant at either a 1% or 5% level. Even though there were some variables that were not significant in the estimation of the final extended model, it was determined that the final model proved to be better with the non-significant variables included, rather than when they were excluded (better log-likelihoods, pseudo R-squareds, AICc’s, and significance of other variables).

From Table 6-15, it can be seen that the coefficients for the constants, “Travel Time”, “Weather Dry” and “Slope Flat” have remained approximately the same, without the parameter estimate altering by more than 10%, except in the case of the Constant for Option A which altered by approximately 20%. This was the situation for the extended recreational model; however this does not have a large impact on the parameter estimates. The significance for these parameter estimates has also remained the same. Therefore the relationships for “Travel Time”, “Weather Dry”, and “Slope Flat” have remained approximately the same as before; however, one can now see how the respondents' personal demographic information affects the choices made. Therefore, for both models when all else is held equal, commute cyclists are willing to increase their travel time by approximately 100% in order to journey along a segregated from traffic cycle facility, and approximately 90% to travel upon a road with a cycle lane. For both models, similarly to the recreational cyclist models, “Weather Dry” had the biggest impact on Option B, followed by Option C and then Option A. “Weather Dry” was the lowest for Option A, consequently it was not such an important issue for Option A, as it was for the others since it was much lower. For “Slope Flat”, each of the parameter estimates increased by approximately 10%. The parameter estimates were largest for Option B, followed by Option C and then Option A. One can surmise that commuters are willing to tolerate some gradients in order to cycle upon some form of cycling infrastructure. “Slope Flat” and “Weather Dry” for Option A were, relative to the other parameter estimates, quite low. This may be due to commuters having more of a focus on travel time, and therefore, many other variables become secondary to travel time. As stated previously, the relationship for “Slope Flat” and the given options may be affected by respondents not fully understanding the gradient condition. The gradient condition was presented last to the respondents, so some respondents may have skipped this condition. They may have already decided what option they would choose by the time they read the gradient condition.

“Age” is positive for Option A, implying that it is more likely that a commute cyclist with a higher age would choose a road without cycling infrastructure. The “Age” parameter estimate is negative for Option B, implying that the recreational cyclists choosing this option would be younger. This was similar to the relationship for the recreational cyclist models. As was seen in the recreational cyclist models, the “Gender” variable for Option A is negative and quite large in scale relative to the negative “Gender” variable for Option B, implying that many more male commute cyclists than females would be willing to select a road without cycling infrastructure. More male commute cyclists than females would be willing to choose Option B also, however, not on as large a scale as Option A. These parameter estimates imply that female commute cyclists have a strong preference for Option C, with few choosing Option B and even fewer choosing Option A. The parameter estimate for “Income” for Option A was positive, and relatively larger than the positive parameter estimate for Option B. This implies that those with higher incomes are willing to choose Option A for commute cycle trips in preference to the other options. The parameter estimate for Option B was positive, but lower than Option B. One can surmise from this that those with a lower income would choose Option C, rather than Options A and B. The “Single” parameter estimate for Option A and Option B are positive, but the parameter estimate for Option B is much larger relative to Option A. Both these parameter estimates imply that single commute cyclists are more likely to choose Option A and Option B, however, more single commuters would select Option B rather than Option A. These parameter estimates imply that those who are not single are more likely to select Option C. As suggested in the recreational model, commute cyclists who are not single, may be more likely to be travelling with either a partner and/or child, and may have a preference for a safer cycling environment, so they would be more inclined to choose Option C. The parameter estimate for Option A is positive but is close to zero, so it might not be an overly influential variable for predicting the choice of Option A. From this analysis, it appears that travel time has the strongest influence in the decision for choosing Option A for a commute trip, and therefore, the other variables are secondary factors and are not overly determinative. The parameter estimates for the variables discussed can be seen in Table 6-15.

Table 6-15 Basic Commute Model Extended to Include Age, Gender, Income and Bicycle Owned

Estimate	Coefficient	Standard Error	Z	|z|>Z*
Option A - Road without cycling facilities				
Constant	-2.34***	0.23	-10.32	0.00
Travel Time	-0.02***	0.01	-4.16	0.00
Weather Dry	0.22*	0.12	1.78	0.07
Slope Flat	0.31***	0.12	2.50	0.01
Age	0.65***	0.15	4.18	0.00
Gender	-0.72***	0.13	-5.52	0.00
Income	0.09***	0.03	2.91	0.00
Single	0.02	0.14	0.17	0.86
Option B - Road with Cycling facilities				
Constant	-1.15***	0.18	-6.33	0.00
Travel Time	-0.05***	0.01	-10.27	0.00
Weather Dry	0.71***	0.10	7.43	0.00
Slope Flat	0.45***	0.10	4.66	0.00
Age	-0.19*	0.11	-1.72	0.08
Gender	-0.10	0.10	-1.05	0.29
Income	0.02	0.03	0.62	0.54
Single	0.24**	0.10	2.29	0.02
Option C - Segregated from Traffic Cycling Facility				
Travel Time	-0.05***	0.00	-14.38	0.00
Weather Dry	0.46***	0.09	5.37	0.00
Slope Flat	0.37***	0.09	4.26	0.00
Sample	**3,380**			
Pseudo R-squared	**0.12**			
Log likelihood	**-2,194.21**			
AICc	**4,426.40**			

*** Significant at a 1% level
** Significant at a 5% level
* Significant at 10% level

The cost coefficients and ratios have been estimated from the travel time parameter estimates in Table 6-15. These coefficients were derived in a similar manner to Table 6-14. It can be seen in Table 6-16 how the cost ratio between Option A and Option B is 1.96. It can be deduced from this ratio that a commute cyclist would be willing to pay 96% more for a cycle lane, than for a road without any cycling facilities. Similarly, a commute cyclist would be willing to pay 118% more for a fully segregated from vehicular traffic cycling facility. The cost per minute of each option was calculated, and the differences between Option A, and Option B and Option C were calculated. It can be seen in Table 6-16 how a commute cyclist would be willing to pay €0.18 per minute to travel upon a cycle lane along a road, rather than a road without any cycling infrastructure. A commute cyclist would be willing to pay

€0.21 per minute to travel along a segregated from traffic cycling facility, over a road without any cycling infrastructure.

Table 6-16 Cost Coefficients Estimates from the Travel Time Parameter Estimate and the Willingness to Pay of Commute Cyclist for Different Cycling Facilities for the Extended Commuter Model

Estimate	Coefficient
Option A - Road without cycling facilities – Cost	-0.05
Option B - Road with Cycling facilities – Cost	-0.10
Option C - Segregated from Traffic Cycling Facility – Cost	-0.11
Ratio of Option A to the other options	
Option A - Road without cycling facilities – Cost	1
Option B - Road with Cycling facilities – Cost	1.96
Option C - Segregated from Traffic Cycling Facility – Cost	2.18
Cost of each Option per minute (€/min)	
Option A - Road without cycling facilities – Cost	€0.18
Option B - Road with Cycling facilities – Cost	€0.36
Option C - Segregated from Traffic Cycling Facility – Cost	€0.39
Willingness to Pay (€/min)	
Extra amount that a commuter would be willing to pay for Option B over Option A	€0.18
Extra amount that a commuter would be willing to pay for Option C over Option A	€0.21

6.6.1 Commute Analysis Conclusions

Research into cycling for commuting purposes has been extensively analysed over the past decade. By including the analysis of commuters with the recreation and tourist analysis, it facilitates a distinct comparison between these three categories to be made possible. This permits the development of the research into tourism and recreation to advance by allowing them to relate to a commuter model. This will enable someone undertaking similar research, to understand how commuters would demand direct routes with some cycling infrastructure, and quantify how much tourists and recreational users would be willing to divert, in order to have safer and better quality cycling infrastructure, in relation to the commuter cyclists.

From the results in this section, it was observed that commuter cyclists, when presented with either a road without cycle lanes, a road with cycle lanes, and a segregated from traffic cycling facility, with all other conditions being equal, the commuter will select the segregated facility approximately 60% of the time, the road with cycle lanes 27% of the time, and the road without any cycling facilities 13% of the time. From the regression analysis performed on this data the following is now known:

- A commute cyclist is willing to increase their cycling travel time by approximately 110% in order to cycle upon a cycling facility which is fully segregated from traffic, rather than along a road without cycling infrastructure, and are willing to increase their travel time by 100% to be able to cycle along a road with a cycle lane, rather than a road without cycling facilities.
- Older, single, male commute cyclists, are more likely to choose a road without cycling facilities or a road with a cycle lane, while younger, female commute cyclists, who are in a relationship, are more likely to choose a road segregated from traffic cycling facility for commute trips.
- Female commute cyclists are very unlikely to use a road without any cycling facilities, and, are unlikely to select a road with cycle lanes. Female commute cyclists have a strong desire to be segregated from traffic. Segregation from traffic was highly influential for females cycling for recreational purposes.
- If there was a tangible cost to using cycling facilities, a commute cyclist would be willing to pay 96% more for a road with cycle lanes, than for a road without cycling facilities and 118% more for a cycling facility which is fully segregated from traffic, than for a road without cycling facilities.
- Using a value of time of €10.98 an hour or €0.18 per minute, it can be deduced that a cyclist is willing to pay €0.18 per minute for a road with a cycle lane, and €0.21 per minute for a cycling facility which is fully segregated from traffic.

6.7 All Trips Stated Preference Analysis

The data for the three models in Section 6.3, 6.4 and 6.5 were combined into one data set, and similar analysis that was carried out in those sections was completed. The combined tourist, recreational, and commute data create the “All Trip” dataset. A summary table of the data that forms the combined model can be seen in Table 6-17.

Table 6-17 Sources of Data for All Trips Model

Data Type	Total Number of Pseudo Respondents	Percentage
Tourist Data	1,444	18
Recreational Data	3,380	41
Commute Data	3,380	41
Total	8,204	100

The options chosen by these respondents from the scenarios are known, as seen in Chapter 5, and the conditions that these choices were made under are also known. This data is inputted into NLogit along with the utility functions from Equations 4-11, 4-12 and 4-13 from section 4.6.1 in Chapter 4. Multinomial logit analysis was performed on the data and functions, and resulted in Table 6-18. NLogit estimates the coefficients for the constants and parameters.

The results in Table 6-18 show that all the estimates had good significance (significance at a 1% and 5% level) with the exception of the "Weather Dry" parameter for "Option A – Road without Cycling Facilities". However, this parameter was significant at a 10% level. As mentioned in Sections 6.5 and 6.6, this could be due to the variables "Travel Time" and "Slope Flat" affecting the choice of a road without cycling facilities most, and weather not being an overly influential factor.

As seen in the tourism, recreational and commute models, the results from Table 6-18 make intuitive sense, with all the beta coefficients being negative for travel time, and positive for both weather and slope. This implies that for all options, as travel time increases for an option, respondents are less likely to choose that option and the more flat and the better the weather is for an option, the more likely that the respondent will choose that facility. The log-likelihood value for this model is -5,296.59. The model tested is better than a constants only model, as the log-likelihood value for a constants only model is -5,637.82 (a lower log-likelihood than the constants only model is desired). The pseudo R-squared value for the model in Table 6-18 is 0.06. The AICc for this model is 10,615.20. These values will be used for the comparison with other models based on the all trip dataset.

From Table 6-18, it can be seen that when all else is held equal, the "Travel Time" parameter estimates for Option A (-0.02) is approximately half of the travel time parameter estimate for Option C (-0.04). This implies that a generic cyclist would be willing to increase their travel time by approximately 130%, in order to travel upon a segregated from traffic cycling facility, rather than upon a road without any cycling infrastructure. The travel time parameter estimate for Option A is approximately 50% of the travel time parameter estimate for Option B. This implies that a tourist would be willing to increase their travel time by approximately 100%, in order to travel along a road with a cycle lane, rather than upon a road without any cycling infrastructure.

As seen in the recreational and commute models, “Weather Dry” is largest for Option B, and this is followed by Option C. This implies that dry weather would be mostly the reason why a commute cyclist would choose Option B, whereas dry weather would seemingly not be as strong an influential factor when choosing Option A. Therefore, if the weather is dry, a respondent is least likely to select Option A. It can be deduced that a generic cyclist would be willing to sacrifice some comfort (cycle in poor weather) in order to travel upon either a cycle lane or a segregated cycling facility.

The parameter estimate for “Slope Flat” is smallest for Option A. The Option B and Option C estimates are much larger. This implies that a greater gradient would be tolerated for Option B and Option C, whereas, only a small gradient would be tolerated for Option A. The parameter estimate for Option B was the largest, but it is slightly larger than Option C. Therefore, it can be reasoned that a generic cyclist is willing to persevere with some increased gradients in order to cycle upon some form of cycling infrastructure. The parameter estimates for this basic generic cyclist model can be seen in Table 6-18.

Table 6-18 Estimates for the Most Basic Commute Model

Estimate	Coefficient	Standard Error	z	|z|>Z*
Option A - Road without cycling facilities				
Constant	-2.05***	0.11	-18.02	0.00
Time	-0.02***	0.00	-4.89	0.00
Weather Dry	0.25***	0.08	3.16	0.00
Slope Flat	0.31***	0.08	3.86	0.00
Option B - Road with Cycling facilities				
Constant	-1.49***	0.10	-14.90	0.00
Time	-0.03***	0.00	-10.55	0.00
Weather Dry	0.72***	0.06	11.29	0.00
Slope Flat	0.41***	0.06	6.51	0.00
Option C - Segregated from Traffic Cycling Facility				
Time	-0.04***	0.05	-16.95	0.00
Weather Dry	0.41***	0.06	7.56	0.00
Slope Flat	0.38***	0.06	6.78	0.00
Sample	**8,204**			
Pseudo R-squared	**0.06**			
Log-likelihood	**-5,296.59**			
AICc	**10,615.20**			

*** Significant at a 1% level
** Significant at a 5% level
* Significant at 10% level

As was completed for the commute, recreational and tourist models, the cost coefficients and ratios have been estimated from the travel time parameter estimates in Table 6-18. These coefficients were derived in a similar manner to Sections 6.4, 6.5 and 6.6. It can be seen in Table 6-19 how the cost ratio between Option A and Option B is 1.73. It can be deduced from this ratio that a generic cyclist would be willing to pay 73% more for a cycle lane, than for a road without any cycling facilities. Similarly, a generic cyclist would be willing to pay 119% more for a cycling facility which is fully segregated from traffic. The cost per minute of each option was calculated and the differences between Option A, and Option B and Option C were calculated. It can be seen in Table 6-19 how a generic cyclist would be willing to pay €0.18 per minute to travel upon a cycle lane along a road, rather than using a road without any cycling infrastructure. A generic cyclist would be willing to pay €0.21 per minute to travel along a segregated from traffic cycling facility, over a road without any cycling infrastructure.

Table 6-19 Cost Coefficients Estimates from the Travel Time Parameter Estimates and the Willingness to Pay of Generic Cyclists for Different Cycling Facilities for the Basic All Trip Model

Estimate	Coefficient
Option A - Road without cycling facilities – Cost	-0.04
Option B - Road with Cycling facilities – Cost	-0.06
Option C - Segregated from Traffic Cycling Facility – Cost	-0.08
Ratio of Option A to the other options	
Option A - Road without cycling facilities – Cost	1
Option B - Road with Cycling facilities – Cost	1.73
Option C - Segregated from Traffic Cycling Facility – Cost	2.19
Cost of each Option per minute (€/min)	
Option A - Road without cycling facilities – Cost	€0.18
Option B - Road with Cycling facilities – Cost	€0.31
Option C - Segregated from Traffic Cycling Facility – Cost	€0.39
Willingness to Pay (€/min)	
Extra amount that a generic cyclist would be willing to pay for Option B over Option A	€0.13
Extra amount that a generic cyclist would be willing to pay for Option C over Option A	€0.21

As in the previous sections, many extensions of the basic generic model were completed. Keeping the model similar to the previously extended tourism, recreational and commute models was an important factor to consider, in order for a comprehensive comparison to be completed between all the models. It was found that the variables tested in the tourist, recreational and commute model again offered one of the best solutions for an extended model, in this instance. The variables used in this extension were the same as the recreational and commute model, therefore the "Bikes Owned" variable was omitted and replaced with the "Single" variable. The "Bikes Owned" variable was again not significant at any level for any option, and it was found that when "Bikes Owned" was replaced by the "Single" variable, there was a marked improvement in significance and the fit of the model. This extension of the basic model proved to be the best for the commute analysis. This model presented the best combination pseudo R-squared, significant variables, log-likelihood, and AICc. Keeping the analysis comparable to the tourist, recreational and commute models allowed similarities and contrasts to be observed, and several conclusions to be formed.

Table 6-20 presents the extension of the basic generic model. The extension contains the original variables of "Travel Time", "Weather Dry" and "Slope Flat", and these are combined with “Age”, “Gender”, “Income” and “Single”. These variables were coded in the same manner as Table 6-10. These estimates improve upon the original basic generic model, as the majority of the variables estimated have good significance, and the model estimated has improved upon the pseudo R-squared, log-likelihood, and the AICc of the basic recreational model. The log-likelihood for the extended recreational model is 5,173.93. This improves upon the log-likelihood of the basic model of 5,296.59. The pseudo R-squared for the extended recreational model is 0.08. This improves upon the original pseudo R-squared for the basic recreational mode of 0.06. The AICc for the extended All Trip model is 10,385.90. This improves upon the AICc of the original basic All Trip model of 10,615.20. These improvements indicate that the extended generic model offers a better alternative to the basic recreational model.

As in the tourism, recreational and commute model, the “Age” variable was the age of the respondents to the survey. This was numerically categorised with 1 representing the 12 – 24 year old age group, and rising to 6 representing the 65+ years of age group. The “Gender” variable represents the gender of the respondents, with 0 being male and 1 being female. The “Income” variable represented the household income of the respondents, which was split into five numerically coded categories, with the lower numbers representing a lower income, and the higher numbers representing higher incomes. The “Single” variable represented the relationship status of the respondent. This variable was again numerically coded with 1 representing a respondent that was “Single” and 0 representing a respondent that was not “Single”. Please see Table 6-10 for how the variables where categorised and the relevant codes attached to them.

“Single” for Option A was the only parameter estimate that was not significant at a 1%, 5% or 10% level. “Income” for Option B was significant at a 10% level, and all the other variables were significant at either a 1% or 5% level. Even though there were some variables that were not significant in the estimation of the final extended model, it was determined that the final model proved to be better with the non-significant variables included, rather than when they were excluded (better log-likelihoods, pseudo R-squareds, AICc’s, and significance of other variables).

From Table 6-20, it can be seen that the coefficients for the constants, “Travel Time”, “Weather Dry” and “Slope Flat” have remained approximately the same without the parameter estimate altering by more than 10%. The significance for these parameter estimates has also remained the same. Therefore the relationships for “Travel Time”, “Weather Dry”, and “Slope Flat” have remained approximately the same as before; however, one can now see how the respondents’ personal demographic information affects the choices made. Therefore, for both models when all else is held equal, generic cyclists are willing to increase their travel time by approximately 100% in order to pass along a segregated from traffic cycle facility, and approximately 50% to travel upon a road with a cycle lane. For both models, “Weather Dry” was highest for Option B, followed by Option C and then Option A. “Weather Dry” was the lowest for Option A, so very few people would select this option if the weather is dry. For “Slope Flat”, the parameter estimates for Option A and Option B increased by approximately 10%, however, there was a decrease of approximately 10% for the parameter estimate for Option C. The parameter estimates were largest for Option B, followed by Option C and then Option A. One can surmise that respondents who select Options B are more sensitive to the route slope, than those who choose Option C, and those that Select Option A are not overly sensitive to route gradient. Therefore, when all options are flat, very few will select Option A. For Option A, “Slope Flat” and “Weather Dry” were, relative to the other parameter estimates, quite low. This may be due to those selecting Option A focusing more on the travel time aspect, and therefore, many other variables become secondary to travel time. There is also the strong possibility that some respondents may have a strong preference for using Option A rather than the other options, and therefore, all other factors become extraneous.

The “Age” parameter estimate is positive for Option A, implying that it is more likely that a generic cyclist with a higher age would choose a road without cycling infrastructure. The “Age” parameter estimate is negative for Option B implying that generic cyclists choosing Option B would be younger in age. This was similar to the relationship for the recreational cyclist models and the commute cyclist model. As was seen in the tourist, recreational and commute cyclist models, the “Gender” variable for Option A is negative and quite large in scale relative to the negative “Gender” variable for Option B, implying that many more male generic cyclists than females would be willing to select a road without cycling infrastructure.

More male generic cyclists than females would also be willing to choose Option B, however, not on as large a scale as Option A. These parameter estimates imply that female cyclists have a strong preference for Option C, with few choosing Option B and even fewer choosing Option A. The parameter estimate for "Income" for Option A was positive and larger than the positive parameter estimate for Option B. This implies that those with higher incomes, are willing to choose Option A for cycle trips over the other options. The parameter estimate for Option B was positive; therefore those on higher income are more likely to select Option B. The "Income" parameter estimates for Option A and Option B were positive, and imply that those with a lower income would choose Option C rather than Option A and Option B. The "Single" parameter estimate for Option A and Option B are positive, but the parameter estimate for Option B is much larger relative to Option A. Both these parameter estimates imply that single cyclists are more likely to choose Option A and Option B, however, more single commuters would select Option B than Option A. These parameter estimates imply that those who are not single are more likely to select Option C. As mentioned in the recreational and commute models, those who are not single are more likely to not be travelling alone (with either a partner or child). Consequently there may be a concern for the safety of those who they are with, and a preference for a safer cycling environment, and therefore, they would be more likely to choose Option C. From this analysis, it appears that travel time has the strongest influence in the decision for choosing Option A for a generic trip, and therefore, other variables become almost superfluous in the decision to choose Option A over the other Options. The parameter estimates for the variables discussed can be seen in Table 6-20.

Table 6-20 All Trip Model including Age, Gender, Income and Bicycle Owned

Estimate	Coefficient	Standard Error	z	|z|>Z*
Option A - Road without cycling facilities				
Constant	-2.28***	0.15	-15.54	0.00
Travel Time	-0.02***	0.00	-4.72	0.00
Weather Dry	0.25***	0.08	3.12	0.02
Slope Flat	0.32***	0.08	4.01	0.00
Age	0.39***	0.10	3.99	0.00
Gender	-0.77***	0.08	-9.1	0.00
Income	0.12***	0.02	5.80	0.00
Single	0.07	0.09	0.82	0.41
Option B - Road with Cycling facilities				
Constant	-1.32***	0.12	-10.98	0.00
Travel Time	-0.03***	0.00	-10.65	0.00
Weather Dry	0.72***	0.06	11.25	0.00
Slope Flat	0.43***	0.06	6.73	0.00
Age	-0.35*	0.07	-4.89	0.00
Gender	-0.24***	0.06	-3.71	0.06
Income	0.03*	0.02	1.84	0.01
Single	0.18**	0.07	2.70	0.01
Option C - Segregated from Traffic Cycling Facility				
Travel Time	-0.04***	0.00	-17.30	0.00
Weather Dry	0.44***	0.06	7.93	0.00
Slope Flat	0.34***	0.06	6.91	0.00
Sample	**8,204**			
Pseudo R-squared	**0.08**			
Log likelihood	**-5,173.93**			
AICc	**10,385.90**			

*** Significant at a 1% level
** Significant at a 5% level
* Significant at 10% level

The cost coefficients and ratios have been estimated from the travel time parameter estimates in Table 6-20. These coefficients were derived in a similar manner to Table 6-19. It can be seen in Table 6-21 how the cost ratio between Option A and Option B is 1.79. It can be deduced from this ratio that a generic cyclist would be willing to pay 79% more for a cycle lane, than for a road without any cycling facilities. Similarly, a generic cyclist would be willing to pay 131% more for a cycling facility which is fully segregated from traffic. The cost per minute of each option was calculated and the differences between Option A, and Option B and Option C were calculated. It can be seen in Table 6-21 how a generic cyclist would be willing to pay €0.14 per minute to travel upon a cycle lane along a road, rather than a road without any cycling infrastructure. A generic cyclist would be willing to pay €0.24 per minute to travel along a segregated from traffic cycling facility, over a road without any cycling infrastructure.

Table 6-21 Cost Coefficients Estimates from the Travel Time Parameter Estimate and the Willingness to Pay of Generic Cyclists for Different Cycling Facilities for the Extended All-Trip Model

Estimate	**Coefficient**
Option A - Road without cycling facilities – Cost	-0.04
Option B - Road with Cycling facilities – Cost	-0.06
Option C - Segregated from Traffic Cycling Facility – Cost	-0.08
Ratio of Option A to the other options	
Option A - Road without cycling facilities – Cost	1
Option B - Road with Cycling facilities – Cost	1.79
Option C - Segregated from Traffic Cycling Facility – Cost	2.31
Cost of each Option per minute (€/min)	
Option A - Road without cycling facilities – Cost	€0.18
Option B - Road with Cycling facilities – Cost	€0.32
Option C - Segregated from Traffic Cycling Facility – Cost	€0.42
Willingness to Pay (€/min)	
Extra amount that a generic cyclist would be willing to pay for Option B over Option A	€0.14
Extra amount that a generic cyclist would be willing to pay for Option C over Option A	€0.24

6.7.1 All Trips Conclusions

This All Trip model will be very useful to any person considering constructing cycling infrastructure, where the potential user group would not be known. This generic model allows for the demands of commute, recreational and tourist users to be catered for, without over compromising any one group in particular. Commuters who demand a more direct route may be affected by this model, in that the model may not select the most direct route, preferring a route with better quality cycling infrastructure. However, the opposite would be true for the recreational and tourist users, who may not have a directness/time demand and would prefer better quality cycling infrastructure, distinct from having a direct route, with only adequate cycling infrastructure.

From the results in this section, it was observed that generic cyclists, when presented with either a road without cycle lanes, a road with cycle lanes, and a segregated from traffic cycling facility, with all other conditions being equal, the generic cyclist will select the segregated facility approximately 65% of the time, the road with cycle lanes 23% of the time, and the road without any cycling facilities 12% of the time. From the regression analysis performed on this data the following is now known:

- A generic cyclist is willing to increase their cycling travel time by approximately 100% in order to cycle upon a cycling facility which is fully segregated from traffic, rather than along a road without cycling infrastructure, and are willing to increase their travel time by 80% to be able to cycle along a road with a cycle lane, rather than a road without cycling facilities.
- Older, single, male cyclists, are likely to choose a road without cycling facilities or a road with a cycle lane, while younger, female cyclists, who are not single, are more likely to choose a road segregated from traffic cycling facility, for commute trips
- Female cyclists are very unlikely to select to use a road without any cycling facilities, and, are unlikely to select a road with cycle lanes. Female cyclists in general have a strong desire to be segregated from traffic.
- If there was a tangible cost to using cycling facilities, a generic cyclist would be willing to pay 96% more for a road with cycle lanes, than for a road without cycling facilities, and 118% more for a cycling facility which is fully segregated from traffic, than for a road without cycling facilities.
- Using a value of time of €10.98 an hour or €0.18 per minute, it can be deduced that a cyclist is willing to pay €0.14 per minute for a road with a cycle lane and €0.24 per minute for a cycling facility which is fully segregated from traffic.

6.8 Discussion of Analysis

Table 6-22 presents the parameter estimates from the extended models estimated for "Tourist", "Recreational", "Commuter", and "All Trips". This allows the variations in parameter estimates to be observed between the four categories. The extended models were chosen for inclusion in this section rather than the basic models, as the extended models improved upon the basic models for all the groups under investigation.

It can be seen that the sign of the coefficients remained the same for the variables across the four models, with the exception of "Age". "Age" is negative for the "Tourist" model and positive for the "Recreational", "Commuter" and "All Trip" models. The variable "Single" can be compared between the "Recreational", "Commuter" and "All Trip" models, however, this variable was not estimated for the “Tourist” model; therefore there the “Tourist” model cannot be included in a comparison of the “Single” variable including. Similarly, the “Bikes Owned” variable was only estimated for the “Tourist” model, and therefore cannot be included when comparing the “Recreational”, “Commuter” and “All Trip” models.

When observing travel time between the options for the four models, it is noted that the relationship remains approximately the same across the models. The parameter estimates are lowest for Option A, and increase for Option B, and are highest for Option C. This demonstrates that there is a clear desire across these four groups for cycling infrastructure, with a segregated cycling facility being the most desired. It is apparent that commuters place a greater value on Option B, than any of the other groups. This is most probably due to the travel time duration being the most important factor for those commuting, and they are the most inclined to select Option B, above the other groups. Tourists and recreational cyclists had the lowest parameter estimates for “Travel Time” for Option B. This is possibly due to those travelling for either tourist or recreational purposes desire a higher quality environment with increased safety, and they are willing to sacrifice some time in order to achieve this. Therefore, if a respondent is travelling for a tourist or recreational related trip, they are more likely to choose Option B in preference to Option A. They are not willing to sacrifice as much time for this option as commuters. For Option C, recreational cyclists were willing to increase their travel time the most in order to cycle upon this option. This is most likely due to recreational cyclists being willing to sacrifice more time in order to cycle upon the segregated cycling facility, than the other groups. Commuters were the next highest variable in willingness to sacrifice time in order to cycle upon a segregated facility. It would be expected that tourists would be the next highest variable. However, when looking at the time parameters for commuters for Option B and Option C, it can be observed that the estimate is very similar, whereas for tourists there is an increase for the travel time parameter between Option B and Option C. The commuters seem to be willing to sacrifice some time for some form of cycling infrastructure, but are not willing to sacrifice much more time in order to cycle upon a higher quality facility. The tourists are willing to increase their travel time substantially more relative to the commuters, in order to cycle upon the segregated cycling facility. Even though the commuters are willing to sacrifice more time for Option C, it is only valued slightly more than Option B. This may be due to commuters having some safety concerns while cycling, and once these have been addressed by having some form of cycling infrastructure present, an increase in quality is not valued as much as the initial provision. The tourists do value some form of cycling infrastructure, which is demonstrated by the increased “Travel Time” parameter estimate, but not as much as the commuters. However, the tourists are willing to increase their travel time for Option C from Option B, but not as much as the increase from Option A to Option B. This indicates that the segregated cycling facility is very much valued by the tourists. The “All Trip” model presents a more linear relationship with the “Travel Time” parameters increasing consistently between the three options. The model averages out the fluctuations in “Travel Time” between the different groups, and presents a generic relationship for all cyclists.

The “Weather Dry” parameter estimate was highest for all models for Option B, second highest is Option C, and then lowest Option A. The replication across all four models indicates that this is not random variance. This pattern could be due to the conjunction of two separate factors in the model:

1. It is believed that those that choose Option A, mostly do so in order to reduce travel time. Therefore, the “Travel Time” parameter might explain most of the variance for Option A, whereas “Weather Dry” may only account for a small part of the variance
2. It is believed that those choosing Option C, mostly do so in order to travel upon a perceived to be safer cycling facility. Similar to Option A, “Weather Dry” may only explain a small part of the variance.

These two factors converging for Options A and Options C may be leading to the “Weather Dry” parameter estimate becoming an important part in explaining the variance for choosing Option B.

The relationships between “Slope Flat” and the options, vary from model to model. As theorised in the previous sections, this varied relationship may be due to some of the respondents not understanding the condition in relation to gradient. It could also be due to the condition being the last condition posed to the respondents and therefore some respondents might ignore the last condition, or some may have already decided what option they would choose before reading the gradient condition. However, for all models, the “Slope Flat” parameter estimate is lowest for Option A, indicating that having a flat gradient is an influential factor for choosing Option A. Option B and Option C have larger parameter estimates for “Slope Flat” indicating that some form of gradients would be tolerated in order to cycle upon some form of cycling infrastructure.

The relationship for “Age” and the options splits the groups. For the tourist group, it is those of a younger age choosing Option A, and those of an older age choosing Option B and Option C. However, for the other three groups, the relationship is reversed. It can be observed that those of an older age are more likely to select Option A, whereas those of a younger age are more likely to select Option B, and Option C.

The relationship for “Gender” and the options is approximately similar across the four models. For the four models, the “Gender” parameter estimate for Option A is large in scale and negative, implying that the majority of those selecting Option A would be male. For Option B, there is a slight divergence for “Gender”, where the parameter estimate being positive for the Tourist model, and negative for the other models. This implies that female tourists would be slightly more likely to select Option B, whereas for the other models, males are more willing to select Option B.

The relationship for the “Income” variable was the nearly the same across all the models, with those having a higher level of income being more willing to select Option A and Option B, while those with a lower income are more willing to select Option C. The relationship for “Income” and the options was approximately linear for the Recreational, Commuter and All Trip models, with the parameter estimates for “Income” being largest for Option A. The parameter estimates for Option B were then the second highest, implying that those with lower levels of income were more likely to choose Option C. The tourist model differed slightly to the other three models. The parameter estimates for the “Income” variable was slightly larger for Option B, compared to Option A. As stated in Section 6.4, this may be due to the diverse range of tourists from which the dataset was derived. In the Americas, it is those with lower levels of income who are more likely to cycle, whereas in Europe, it is the opposite, with those having higher levels of income being more likely to cycle. The tourist dataset contained a mixture of tourists from around the world, and this most probably causes the variation for the income relationship, from the other models.

The variable “Single” was estimated for the Recreational, Commuter and All Trip models, but not for the Tourist model. The three models showed an increase in the parameter estimates from Option A to Option B. The scale of the increase varied between the three models. For the recreational model there was only a slight increase from Option A to Option B. For the commuter model, there was a large increase from Option A to Option B. Both parameter estimates for Option A and Option B were positive, therefore, it can be inferred that those who are not in a relationship are more likely to select Option B over Option A. Those who are in a relationship are most likely to select Option C.

The “Bikes Owned” variable was only estimated for the Tourist model, but as before, it can be seen that the more bicycles that a household possesses, the more likely that a tourist will select Option A, followed by Option B. Whereas households with fewer or no bicycles, are more likely to select Option C. As mentioned in Section 6.3, this is most likely due to tourists from households with more bicycles being more likely to cycle, having a greater confidence when cycling, thus they are more likely to be comfortable in cycling amongst traffic and choose Option A. The parameter estimates for all the variables for all the models can be viewed in Table 6-22.

Table 6-22 Tourist, Recreational, Commuter and All Trip Extended Models

Estimate	Tourist	Recreational	Commuter	All Trip
Option A - Road without cycling facilities				
Constant	-2.21***	-2.22***	-2.34***	-2.28***
Travel Time	-0.03**	-0.01	-0.02***	-0.02***
Weather Dry	0.26	0.28**	0.22*	0.25***
Slope Flat	0.62**	0.24**	0.31***	0.32***
Age	-0.24***	0.58***	0.65***	0.39***
Gender	-0.64***	-0.86***	-0.72***	-0.77***
Income	0.07	0.12***	0.09***	0.12***
Single	-	0.20	0.02	0.07
Bikes Owned	0.35***	-	-	-
Option B - Road with Cycling facilities				
Constant	-2.44***	-1.39***	-1.15***	-1.32***
Travel Time	-0.04***	-0.01***	-0.05***	-0.03***
Weather Dry	0.84***	0.72***	0.71***	0.72***
Slope Flat	0.71***	0.32***	0.45***	0.43***
Age	0.06	-0.34***	-0.19*	-0.35*
Gender	0.20	-0.32***	-0.10	-0.24***
Income	0.12**	0.01	0.02	0.03*
Single	-	0.22**	0.24**	0.18**
Bikes Owned	-0.05	-	-	-
Option C - Segregated from Traffic Cycling Facility				
Travel Time	-0.05***	-0.02***	-0.05***	-0.04***
Weather Dry	0.58***	0.43***	0.46***	0.44***
Slope Flat	0.70***	0.33***	0.37***	0.34***
Age	0.08*	-	-	-
Gender	0.13	-	-	-
Income	-0.15***	-	-	-
Bikes Owned	-0.07	-	-	-

Table 6-23 displays the willingness to pay of the four groups analysed in Sections 6.4, 6.5, 6.6, and 6.7. Option A was used as the reference category for all the models tested. Table 6-23 displays the extra amount that an individual from each group would be willing to pay in order to cycle upon Option B and Option C, so avoiding use of Option A.

It can be observed that an individual from the tourist group and an individual from the recreational group would both be willing to pay approximately the same, in order to travel upon Option B instead of Option A. However, the willingness to pay of tourists is not similar to those of the recreational group for Option C over Option A. The willingness to pay of recreational cyclists for Option C over Option A is approximately double that of tourists. The author expected these categories to be broadly similar in estimation. The difference in willingness to pay of the tourists and recreational cyclists may be due to tourists desiring not only to cycle upon segregated cycling infrastructure, but along cycling infrastructure that connects with tourist attractions. A recreational cyclist's desire for sightseeing may not be as high as that of a tourist's and therefore, the type of cycling infrastructure upon which the recreational cyclist cycles may be more of priority, than the tourists. The willingness to pay of commuters for Option B over Option A is approximately double that of both the tourists and recreational cyclists. This is most likely due to those cycling for commute purposes desiring the most direct and quickest route. Having some form of cycling infrastructure on the most direct route seems to be particularly desirable to commuters. The willingness to pay for commuters for Option C over Option A however is much less than the tourists and the recreational cyclists. The willingness to pay of the generic cyclist can be seen to reduce some of the extreme variations between the three groups, and allows for a general willingness to pay of cyclists for differing cycling facilities to be formed.

Table 6-23 Willingness to Pay of the Different Categories of Users

Willingness to Pay for Tourists (€/min)	
Extra that a tourist would be willing to pay for Option B over Option A	€0.09
Extra that a tourist would be willing to pay for Option C over Option A	€0.19
Willingness to Pay Recreational Cyclists (€/min)	
Extra that a recreational cyclist would be willing to pay for Option B over Option A	€0.10
Extra that a recreational cyclist would be willing to pay for Option C over Option A	€0.36
Willingness to Pay for Commuters (€/min)	
Extra that a commuter would be willing to pay for Option B over Option A	€0.18
Extra that a commuter would be willing to pay for Option C over Option A	€0.21
Willingness to Pay for All Trip purposes (€/min)	
Extra that a generic cyclist would be willing to pay for Option B over Option A	€0.14
Extra that a generic cyclist would be willing to pay for Option C over Option A	€0.24

As identified in Chapter 2, research into cycling for recreational and tourist purposes has not received much attention in academic research. The author believes that this is a very important area that requires attention, as in Ireland, 75% of all trips undertaken are for non-commute purposes (Central Statistics Office, 2009). The research that presently exists is aligned more towards cycling for commuting. By looking at the areas of recreational and tourist cycling, there is now a greater understanding of these cycle trips that account for a considerable amount of trips undertaken.

6.9 Conclusions

The investigation in this chapter has allowed several conclusions to be formed in relation to how various environmental factors and demographic attributes affects different groups of people in relation to different standards of cycling facilities. The following is now known:

- From the analysis into tourists:
  - A tourist is willing to increase their cycling travel time by approximately 100% in order to cycle upon a cycling facility which is fully segregated from traffic, rather than along a road without cycling infrastructure, and are willing to increase their travel time by 40-50% to be able to cycle along a road with a cycle lane, rather than a road without cycling facilities.
  - Younger, male tourists, who own one or more bikes are more likely to choose a road without cycling facilities, while older, female tourists, who do not own any bikes, are more likely to choose a road with cycle lanes or a segregated from traffic cycling facility.
  - Female tourists are very unlikely to use a road without any cycling facilities, however, once there is some form of cycling infrastructure a female tourist will be satisfied, be it segregated from traffic or not. Segregation from traffic was not highly influential for females.
- From the analysis into recreational cyclists:
  - A recreational cyclist is willing to increase their cycling travel time by approximately 200% in order to cycle upon a cycling facility which is fully segregated from traffic, rather than along a road without cycling infrastructure, and are willing to increase their travel time by 32% to be able to cycle along a road with a cycle lane, rather than a road without cycling facilities.
  - Older, single, male recreational cyclists, are more likely to choose a road without cycling facilities, or a road with a cycle lane, while younger, female recreational cyclists, who are in a relationship, are more likely to choose a segregated from traffic cycling facility.
  - Female recreational cyclists are very unlikely to select to use a road without any cycling facilities, and, are unlikely to select a road with cycle

lanes. Female recreational cyclists have a strong desire to be segregated from traffic. Segregation from traffic was highly influential for females when cycling for recreational purposes.

- From the analysis into commuters:
    - A commute cyclist is willing to increase their cycling travel time by approximately 110% in order to cycle upon a cycling facility which is fully segregated from traffic, rather than along a road without cycling infrastructure, and are willing to increase their travel time by 100% to be able to cycle along a road with a cycle lane, rather than a road without cycling facilities.
    - Older, single, male commute cyclists, are more likely to choose a road without cycling facilities or a road with a cycle lane, while younger, female commute cyclists, who are in a relationship, are more likely to choose a road segregated from traffic cycling facility for commute trips.
    - Female commute cyclists are very unlikely to select to use a road without any cycling facilities, and, are unlikely to select a road with cycle lanes. Female commute cyclists have a strong desire to be segregated from traffic. Segregation from traffic was highly influential for females cycling for recreational purposes.
- From analysis into all the data combined, forming an “All Trip” model:
    - A generic cyclist is willing to increase their cycling travel time by approximately 100% in order to cycle upon a cycling facility which is fully segregated from traffic, rather than along a road without cycling infrastructure, and are willing to increase their travel time by 80% to be able to cycle along a road with a cycle lane, rather than a road without cycling facilities.
    - Older, single, male cyclists, are likely to choose a road without cycling facilities or a road with a cycle lane, while younger, female cyclists, who are not single, are more likely to choose a road segregated from traffic cycling facility, for commute trips.

  - Female cyclists are very unlikely to select to use a road without any cycling facilities, and, are unlikely to select a road with cycle lanes. Female cyclists in general have a strong desire to be segregated from traffic.

The analysis in this chapter also allowed for the calculation of the willingness to pay of the various categories of cyclist for differing standards of cycling facilities.

- A tourist is willing to pay €0.09 for a cycle lane along road over a road without cycling facilities.
- A tourist is willing to pay €0.19 for a segregated cycling facility over a road without cycling facilities.
- A recreational cyclist is willing to pay €0.10 for a cycle lane along road over a road without cycling facilities.
- A recreational cyclist is willing to pay €0.36 for a segregated cycling facility over a road without cycling facilities.
- A commuter is willing to pay €0.18 for a cycle lane along road over a road without cycling facilities.
- A commuter is willing to pay €0.21 for a segregated cycling facility over a road without cycling facilities.
- A generic cyclist is willing to pay €0.14 for a cycle lane along road over a road without cycling facilities.
- A generic cyclist is willing to pay €0.24 for a segregated cycling facility over a road without cycling facilities.

In conclusion, it was determined that a recreational cyclist was willing to pay the most for a segregated cycling facility, followed by a commuter, and the tourist was willing to pay the least. In general, older males were more willing to cycle upon roads without cycling facilities than younger females. A generic cyclist is willing to increase their travel time by approximately 100% is order to travel upon a segregated cycling facility. In general, all groups were willing to tolerate an increase in gradients, in order to cycle upon some form of cycling infrastructure.

7 Estimating the Health Benefits of Cycling

7.1 Introduction

This chapter looks the health economic benefits from the construction of the proposed cycle route through the study area outlined in Chapter 1. The health economic benefits were estimated using the World Health Organisation's (WHO) Health Economic Assessment Tool (HEAT). This tool can be used to calculate the health economic benefits from an intervention (construction of a new cycling facility). The data used for this tool was retrieved from the stated preference survey that was undertaken in the study area in 2012 and 2013. In total there were 845 responses to this survey.

The HEAT was developed by the WHO in 2011 (WHO, 2012). The HEAT tool was specifically developed to measure the health benefits of cycling and to place an economic value on these benefits (WHO, 2012). The purpose of this tool is to create an economic assessment of cycling infrastructure and policies. This tool can be used to examine both existing infrastructure and policies, and analyse the potential benefits of proposed infrastructure and policies.

The HEAT tool was selected over other similar appraisal tools as it is based on an extensive review by the WHO. The WHO performed a systematic review of economic and health literature from around the world, that examined assessments of various transport projects and epidemiological literature concerning the various health effects that accrue from cycling. The review was based on academic research, government reports and other relevant literature which allowed for this comprehensive tool to be created and applied around the world. The tool is easily adapted and allows national and local factors, such as mortality rates, inflation rates, current travel modes, and the relevant value of a statistical life to be included in the analysis. This allows the tool to be included in analysis around the world, as the applicable local effects can be incorporated. The results of the tool can be easily understood, and used in comparisons of similar projects around the world. For more information on measuring the health benefits of cycling please see Section 2.6 of Chapter 2.

The tool was created as a way to measure the economic impact of combating physical inactivity, which is a significant health problem in many regions of the world. The solution to this problem is not simple and requires a macroscopic view on all aspects of day to day living. One area that has been identified as having the potential for increasing physical activity is transport. In order to increase active travel, this area needs to be fully understood. The HEAT tool allows an understanding of proposed health benefits of active travel to be developed and then to be financially quantified.

In many cases, the financial benefits derived from increased cycling from a new policy or new piece of cycling infrastructure may not have direct tangible financial benefits. For instance, when a new toll road would is considered, the main financial benefits can be attributed to time savings, reduction in traffic, etc, and the payment of the tolls are a direct and easily quantifiable way of determining the return on the investment. For the type of analysis considered in this chapter, the economic gains are derived mostly from increased health benefits. The calculation of the return on a potential investment from increased health can be a very difficult issue to assess, however HEAT provides a methodology to measure these economic impacts. Increasing the health of a population as a whole usually leads to several marked improvements in many areas. For instance, if the working population is healthier, then there are less sick days taken annually and therefore the population becomes more productive (WHO, 2012). Another aspect is a reduced mortality rate. By reducing the mortality rate, more people are living (longer) and working longer. This healthier population also results in a decrease in the cost of running the health services, as there will be less demand from a healthier population (WHO, 2012). The HEAT tool factors these benefits into the financial analysis of an investment in infrastructure or policy.

7.2 How HEAT works

Specific information regarding cycling in the area needs to be gathered before the HEAT analysis can commence. The basic process and formulas upon which HEAT is as follows:

Step 1. Volume of Cycling Per Person:

- This step requires information on duration, distance, and frequency of cycling trips.

Step 2. Protective Benefit:

- This step looks to calculate the present reduction in mortality rate from those cycling. The reduction in mortality rate as a result of cycling is calculated using Equation 7-1.

Equation 7-1

$$Reduction\ in\ Mortality = 1 - (Relative\ Risk)^{\frac{Volume\ of\ Cycling}{Reference\ Volume\ of\ Cycling}}$$

Step 3. Population that Stands to Benefit:

- This step repeats Step 1 and Step 2, except adjusted for the predicted levels of the population that stands to benefit from an intervention.

Step 4. General Parameters:

- This step requires information on the intervention such as the build-up period, the present mortality rate in the country, and over what time frame the benefits are to be measured.

Step 5. Estimate of Economic Savings:

- This step combines the results of the previous steps and outputs the estimated benefits from an intervention. These benefits include:
    - i. A benefit cost ratio based on the input costs of the intervention.
    - ii. Reduction in mortality rate.
    - iii. The value of a reduction in mortality rate.
    - iv. Total value of all benefits from the intervention.

From the WHO (2012), it is known that the HEAT tool uses estimates of the relative risk of death from any cause among regular cyclists, compared to people who do not cycle regularly. It is based on relative risk data from studies from around the world. The relative risks are applied to the amount of cycling entered by the analyst and a log-linear relationship is assumed between cycling and mortality. In order to prevent inflated values and to keep the analysis accurate, the risk reduction is capped at approximately 50%. The tool uses the mortality rate to calculate the number of people who would normally be expected to die in any given year in the study population. Succeeding this, the reduction in expected deaths in the study population that cycle is calculated from the adjusted relative risk. The tool produces an estimate of economic savings from this calculated reduction in deaths.

The versatility of the structure of the HEAT tool proves to be very useful. This tool can be used to identify the economic benefits of different government policies that encourage cycling (such as a tax relief scheme for purchasing bicycles) or used to determine the advantages of differing standards of cycling facilities. This is done so by allowing unbiased comparisons to be made between various projects and permit an objective opinion to be made purely on the economic health merits of each individual proposal.

The HEAT analysis conducted in this thesis was applied to the area surrounding the proposed cycle route. The cycle route that is planned is along a disused towpath of a canal. The cycle route will be fully separated from any vehicular traffic. The proposed route is approximately 60km long and varies greatly in condition. Some sections of the route are presently used as local roads whereas other sections are overgrown and have become flooded by the canal. For more information on the route and alignment please see Section 1.1 of Chapter 1.

7.3 HEAT Methodology

This section looks at the process that was used to determine the health economic benefits of an intervention. The information required, how it was attained and the analysis performed on the information is outlined. For more information on the methodology used, please see Section 4.5 and 4.13 of Chapter 4.

As seen in the steps outlined in the Section 7.1, before the HEAT analysis could be performed, specific information regarding cycling in the study area needed to be gathered. Please see Section 4.6 in Chapter 4 for details on the methods used to collect this sample. These institutions and groups were located within 1km of a proposed high quality cycle route. Extensive analysis was also conducted into the census statistics of the electoral districts located within the buffer zone of 5km.

The design and layout of the HEAT tool was studied and the logic behind the process was mapped. This allowed the key questions to be identified, along with the shortest method through the logic process. The shortest method was chosen so as to minimise respondent fatigue. For the present day evaluation of cycling benefits, information was required on the number of trips per day, per person, and the number of days on average a person cycles. The average distance of these trips, and the number of people undertaking these trips also needed to be identified. From this, a baseline was established, from which, the benefits of an intervention (new cycling infrastructure) could be determined. Following from the establishment of a baseline, information on the potential and predicted usage from an intervention is necessary. The information required is the same as the pre-intervention data, except that this data is what is predicted and therefore determines the potential benefits. For a more detailed description of this process please consult 3.13 of Chapter 4.

In Figure 7-1, the questions used to extract the necessary information can be seen. The questions posed were in relation to the regularity present day cycling of the cycling, and commute distance and time. The respondents were presented with "What if" questions in relation to the creation of a high quality cycling facility along the proposed cycle route. The other questions posed in the survey can be viewed in Appendix 3.

Section 1 - General Questions

*** Do you presently cycle to and from NUIM?**

- Yes
- No

How far from NUIM do you live?

- Less than 3km
- Between 3km and 5km
- Between 6km and 10km
- Between 11km and 20km
- Over 20km
- Work from home

Other (please specify)

What is your travel time to NUIM?

- Less than 5 minutes
- Between 6 minutes and 10 minutes
- Between 11 minutes and 20 minutes
- Between 21 minutes and 40 minutes
- Over 40 minutes
- Work from home

Other (please specify)

If a High Quality Cycling Facility Existed in your Area

Segregated from Traffic, High Quality Cycling Facility:

*** If a high quality Greenway/cycle path like the one pictured above was constructed along the Royal Canal Towpath with direct access to NUIM, would you use this facility: (The facility would be fully seperated from vehicular traffic)**

	Yes	No
To access NUIM?	○	○
For recreational/shopping purposes?	○	○

*** And how often would you use the facility for commuting to and from your place of work or education?**

- Almost every day
- 1-2 times a week
- 1-2 times a month
- 1-2 times a year
- Never

Figure 7-1 Screenshot of Questions Pertaining to the HEAT Analysis

7.4 Data Gathered

The personal information of the respondents and the demographic information from the census data from the study area and the national census statistics can be viewed in Table 7-1. The census statistics were gathered from the POWSCAR dataset which is produced by the Central Statistics Office in Ireland (Central Statistics Office, 2012). This dataset is compiled from anonymised records from a national census undertaken on the night of the 10th of April, 2011. The census statistics from the study area in Table 7-1 compares favourably to the national census statistics in terms of providing a representation of the country. It can then be seen that many of the categories from the stated preference survey are comparable to the census statistics from the local study area and the national census statistics.

There are some instances of differences between the demographics represented in the stated preference survey, and the census statistics. There are more female respondents than male respondents, whereas nationally and in the study area, there are more males, however, there are only slightly more females than males with 36% of respondents being male and 39% being female. Regarding educational attainment, the primary and secondary education obtained category is in line with the national and local census statistics. Completion of third level education is quite prominent in the stated preference survey when compared to the census statistics. This is most likely due to the stated survey being undertaken in a third level institution and in two information technology companies where there would be a higher percentage of people with third level education. The age category from the census results underestimates the number of people in the 15 to 19 years of age group. This occurs because POWSCAR only includes people who list a profession. Many students do not list a profession as they might not consider studying a profession. Therefore, many people are omitted. Those that have not indicated a profession are classified as missing. Therefore, a considerable amount of the missing category for the Age category of the table could fall into the 15 to 24 age group. Most of the student category would fall into this age grouping. There was also over sampling of non-married people, but this was most likely due to the younger age group sampled in the stated preference survey. The level of cycling in the survey cycling was quite high relative to the census statistics. This was most likely due to those who presently cycle being more willing to partake in a survey on cycling than those who do not cycle. Whilst there are some small discrepancies between some categories from the stated preference survey, and the national and local census statistics, the stated preference provides a broadly representative sample of the study area and the country.

Table 7-1 Data from Stated Preference Survey, Census Statistics from the Study Area, and the National Census Statistics

Demographics from Stated			**Census Statistics From Study**			**Census Statistics for the**		
Gender	Number	%	**Gender**	Number	%	**Gender**	Number	%
Male	304	36	**Male**	73,616	52	**Male**	144,6963	52
Female	327	39	**Female**	68,161	48	**Female**	133,6973	48
Missing	214	25	**Missing**	0	0	**Missing**	0	0
Total	845	100	**Total**	141,777	100	**Total**	278,3936	100
Education								
Primary,	253	30	**Primary,**	43,372	31	**Primary,**	822,363	30
Third Level	374	44	**Third Level**	8,581	6	**Third Level**	190,929	7
Missing	218	26	**Missing**	89,824	63	**Missing**	1,770,644	63
Total	845	100	**Total**	141,777	100	**Total**	2,783,936	100
Age								
15-24	214	25	**15-24**	6,524	5	**15-24**	126,592	5
25-34	256	30	**25-34**	28,523	20	**25-34**	518,514	19
35-44	111	13	**35-44**	26,596	18	**35-44**	475,689	17
45-54	122	15	**45-54**	17,918	13	**45-54**	383,247	14
55-64	93	11	**55-64**	8,986	6	**55-64**	222,100	8
65+	35	4	**65+**	1,276	1	**65+**	44,502	2
Missing	15	2	**Missing**	51,954	37	**Missing**	101,3292	35
Total	845	100	**Total**	141,777	100		2,783,936	100
Marital Status								
Single	430	51	**Single**	31,880	22	**Single**	680,216	25
Married	193	23	**Married**	57,943	41	**Married**	1,090,428	39
Missing	222	26	**Missing**	51,954	37	**Missing**	1,013,292	36
Total	845	100	**Total**	141,777	100	**Total**	2,783,936	100
Means of Travel – Commute								
Drive	312	37	**Drive**	66,163	47	**Drive**	1,255,699	46
Drive	32	4	**Drive**	23,297	17	**Drive**	508,338	18
Walk	129	15	**Walk**	21,481	15	**Walk**	414,938	15
Cycle	228	27	**Cycle**	2,443	2	**Cycle**	61,177	2
Bus	77	9	**Bus**	15,841	11	**Bus**	288,562	10
Rail	64	8	**Rail**	5,181	4	**Rail**	70,976	3
Other	0	0	**Other**	4,065	4	**Other**	104,853	3
Missing	3	0	**Missing**	3,206	3	**Missing**	79,393	3
Total	845	100	**Total**	141,777	100	**Total**	2,783,936	100

7.5 HEAT EVALUTION

The HEAT analysis undertaken in this thesis looks solely at commute trips. As the census statistics do not gather information on non-utility related trips, it would be inaccurate to formulate HEAT estimation for non-utility trips. Therefore, this section looks solely at work and education related trips. As commuting trips represent typically only 25% of trips in Ireland, the benefits estimated in this section are likely to underestimate the true economic benefits of introducing the new cycling facility (Central Statistics Office, 2009).

Presently, it can be seen from Table 7-2 that the population of the area surrounding the preferred cycle route is 141,777 people. Of those, there are 2,443 people who cycle for commuting to and from their place of work and education. This represents a work/education travel modal share of 1.72%, compared to the national average of 2.2%. The section of the 2011 census regarding modes of transport to and from places of work and education was restrictive in terms choice. This section only allowed for one mode of transport to be selected. Therefore, those that use multiple modes on their respective commute, or those that vary there modes regularly are excluded from a mode that they may actually use frequently. Those that may cycle to and from their place of work or education one or two days a week, or those that cycle dependent on weather or time of the year are omitted from cycling mode the POWSCAR dataset. Those that commute by bicycle on an irregular or reduced basis are omitted completely and therefore may account for the relatively low cycle rate.

When the results from the stated preference survey are compared to the census statistics, it can be observed how the rate of cycling is overstated in the survey. This is most likely due to people who cycle having an interest in participating in a survey on cycling whereas people who do not cycle might not have an interest in partaking in the survey. It can be seen in Table 7-2 that cycling is overstated in the survey by a factor of approximately 15. If the results from the stated preference survey were extrapolated to the population within the catchment zone, one would infer that there are 38,422 people cycling to and from work and education, whereas the census results state that there are 2,443 people cycling to and from their place of work and education. This overstates the actual numbers that cycle by a factor of over 15. This overstatement may also be as a result of the potential understatement of the cycle rate in the local area from POWSCAR dataset due to restrictive nature of the commute section of the results. The results from the stated preference survey indicate that approximately 50% of respondents who presently do not cycle, but would cycle to and from their place of work and education, if a cycling facility was constructed as proposed. If this figure was used in the HEAT analysis, it would suggest that of the 103,335 people that fall into this category within the catchment area, 51,845 people would start cycling to and from work. This would represent an approximate 2,000% increase in people cycling. This type of increase in modal shift is very unlikely, and the results of any analysis conducted based upon this assumption would be unreasonable and inaccurate.

Table 7-2 Census Statistics from the Electoral Districts that Lie Within the 5km Buffer Zone around the Preferred Route and Stated Preference Results Combined

Census Statistics and Stated Preference Survey Combined	
Population in 5km buffer	141,777
People who Cycle to and from work (Numbers)	2,443
People who Cycle to and from work (Percentage of Populations)	1.72%
Extrapolating Results From Stated Preference Survey to Population in Study Area	
Estimated Population who Cycle to Work	38,422.41
Actual Population who Cycle to Work	2,443
Extrapolating the Number of People who said they would Cycle to the Population	51,845
Survey Predicts People Cycling will increase	2,122%

It was therefore decided to complete a modal shift analysis on the surrounding population. Farrell et al (2010) completed a modal shift study on a rural town. The authors of this paper sought to evaluate the potential environmental benefits of a modal shift of certain percentages from those commuting by unsustainable modes to sustainable modes. The authors used modal shifts in the population of 5% and 10%. It was determined that similar percentages would also be appropriate for the analysis of the population in the study area, given the unrealistic changes in cycling number suggested previously. Table 7-3 displays the present population and the present cycling percentage rate and the number of people cycling. Table 7-3 then displays the numbers if this cycling rate were to increase to 2.5%, 5% and 10%. It can be seen that if the cycling rate were to go from 1.72% to 2.5%, the number of people cycling would increase from 2,443 to 3,544, and if the cycling rate increased to 10%, the numbers cycling would be 14,178.

Table 7-3 Population and Cycling Rates

Cycling Rate	Number	Percentage
Presently Cycling in Study Area at 1.72%	2,443	2
If the cycle rate was to increase to 2.5%	3,544	3
If the cycle rate was to increase to 5%	7,089	5
If the cycle rate was to increase to 10%	14,178	10

Another important factor for the HEAT analysis is travel distance and the days travelled. Presently in Ireland, the Central Statistics Office does not compile information on travel distance. For the HEAT analysis, the average distance commuted by cyclists in the stated preference survey was used. The number of days per year cycled is also required for the HEAT analysis. This figure again is not in the Census statistics, and therefore the figure from the stated preference survey was used (8km). The number of days that people cycle on average in a year by those sampled is displayed in Table 7-4. This is accompanied by the potential increase if the Greenway were constructed. It can be seen in Table 7-4 that if the Greenway were constructed, the number of days cycled could potentially increase from 48 days per year to 78 days per year. This represents an increase of 30 days or approximately 63% from present day figures. This was calculated by firstly establishing the average days commuted by those who presently commute by bicycle only. The average days that would be commuted by those that stated they would commute by bicycle was then calculated. This allowed the potential increase in days cycled to then be estimated. This was repeated for the average distance. The average distance commuted by those who presently cycle was calculated first by omitting the responses of the other modes. The responses of those who said they would cycle if the proposed cycling facility were built were then detached from the overall group. The average distance commuted by this group was then calculated. It can be seen that presently the average distance commuted by those presently cycling is approximately 8km. The average distance commuted by those who presently do not cycle but would if the proposed cycle infrastructure was built is approximately 12km. We can see in Table 7-4 that this represents a growth in the cycling commute distance of 4km or 50%.

Table 7-4 Days and Distances Presently Cycled and Predicted

Number of Days Cycled on Average Per Year	48 Days/year	
If the Greenway were built, Number of Days Cycled on Average Per Year	78 days/year	
Increase in Days Cycled on Average Per Year	30	63%
Average Distance Commuted by those who Cycle	8km	
Average Distance Commuted by those who Don't Cycle and Would Cycle	12km	
Increase in Distance Cycled on average per year	4km	50%

The information from Tables 7-3 and 7-4 were inputted into the HEAT tool. The HEAT tool firstly requires the information on current cycling. This produces a preliminary report outlining a reduction in risk of mortality and the average distances cycled by the population in a year. Presently, the population that cycle has reduced their risk of mortality by 16%. If the facility was built and the predicted increase in cycling was to occur, the reduction in the risk of mortality would be 35%. This represents an average decrease in mortality in the population who cycle of 18%. It can be seen in Table 7-5 that if the cycle route were constructed, the numbers commuting by bike and the distances commuted would increase substantially and lead to a major increase in health benefits for those presently not cycling. Depending on the modal shift, the increased numbers that would stand to benefit from this would vary from 1,101 for a modal share of 2.5% and up to 11,735 for a modal share of 10%. The results of the cycling summary can be viewed in Table 7-5.

Table 7-5 Cyclist Summary from HEAT

Summary of cycling data	**2.5% Modal Shift**	**5% Modal Shift**	**10% Modal Shift**
Pre-intervention cycling data			
Average number of cycling trips per person per year:	96	96	96
Average distance cycled per cycling trip (km):	8	8	8
Average distance cycled per person per year (km):	803	803	803
This level of cycling is likely to lead to a reduction in the risk of mortality of:	16%	16%	16%
Total number of individuals regularly doing this amount of cycling:	2,443	2,443	2,443
Post-intervention cycling data			
Average number of cycling trips **per person** per year:	156	156	156
Average distance cycled **per cycling trip** (km):	12	12	12
Average distance cycled **per person** per year (km):	1,933	1,933	1,933
This level of cycling is likely to lead to a reduction in the risk of mortality of:	34%	34%	34%
Total number of individuals regularly doing this amount of cycling:	**3,544**	**7,089**	**14,178**
Average amount of cycling per person per year increased between pre and post data.			
This change results in a decrease in the average mortality risk for your population of cyclists of:	18%	18%	18%
Number of individuals cycling increased between pre and post data.			
Additional individuals regularly cycling, compared to the baseline	1,101	4,646	11,735

Succeeding the cycle summary is the HEAT estimate. As stated previously, the HEAT estimate requires information on the intervention. The proposed cycle route is approximately 60km long. Cycling infrastructure of this type in Ireland and the UK vary greatly in price, with costs ranging from approximately €10,000 per kilometre to approximately €500,000 per kilometre (Transport for London, 2005), and in one extreme case over approximately €1,760,000 per kilometre (Dublin City Council, 2012). The €1,760,000 per kilometre figure for cycling infrastructure was exceptional, as this required instalment of cycling signals at traffic lights and the reprogramming of many major traffic signalled junctions in the city centre. The proposed cycle route is planned to be of a very high standard and therefore in order to prevent an overestimation of the benefits, a conservative figure of €200,000 per km was used for the estimation of the construction costs of the cycle route. This would lead to a total construction cost of €12 million. This was the figure that was used for the estimation of the cost of intervention for the HEAT analysis and was used in the calculation of the benefit cost ratio. The statistical value of life used in the estimation was €1,574,000 which is the average statistical value of life in the European Union (WHO, 2011). This value is the suggested value from the WHO for the HEAT estimation.

From the case study of the Great Western Greenway in Mayo, it was observed that the uptake in cycling was very quick (Deenihan et al, 2013) (see Section 4.2 of Chapter 4 for more information about this). Within a year of the full facility opening, the usage reached a very high plateau and has remained approximately constant since then. Therefore, for the HEAT analysis in this section, it was assumed that it would take 2 years for the uptake in cycling to be maximised. As there are many similarities with the proposed facility and the Great Western Greenway, this is believed to be a reasonable expectation.

From Table 7-6, the decreased mortality risks can be seen for the varying modal shifts. The number of deaths reduced per year from the decreased mortality rate varies between 3.39 and 17.93, depending on the modal shift. The HEAT model assumes that once the facility is constructed, that it would take two years for the uptake in cycling to expand and it would take five years before the benefits of this uptake would apply. Therefore, for an assessment over a ten year period, HEAT estimates that the benefits are between €37 million and €196 million over ten years or between €3.7 million and €19.6 million per year dependent on modal switch. HEAT estimates that the benefits are maximized in year 7 when the health benefits have fully accrued and the rate of cycling has been maximized. The HEAT model is able to calculate the maximum financial health benefits from year 7 on. After year 7, the annual financial health benefits are between €5.3 million and €28.2 million, dependent on the modal switch. As this analysis is undertaken over a ten year period, it is important to take inflation into consideration. The WHO suggested a discounted rate of 5% per annum for HEAT estimation. Therefore, with the discounted rate applied to the benefits over ten years, the benefits vary between €26.7 million and €141 million or on average between €2.7 million and €14 million per annum. Therefore, with an initial investment of €12 million, this represents benefit cost ratios of between 2.22:1 and 11.77:1. It is important to remember when viewing these results that HEAT does not calculate risk reductions for individual persons, but an average across the population under study. The results should not be misunderstood to represent individual risk reductions.

Table 7-6 HEAT Estimate

HEAT estimate	**2.5% Modal Shift**	**5% Modal Shift**	**10% Modal Shift**
This change results in an decreased in the average mortality risk for your population of cyclists of:	18%	18%	18%
The number of individuals cycling has increased between your pre and post data.			
Additional individuals regularly cycling compared to the baseline.	1,101	4,646	11,735
Taking this into account, the number of deaths per year that are prevented by this change in cycling is:	3.39	8.19	17.93
Financial savings as a result of cycling			
The value of statistical life applied is:	€1,574,000	€1,574,000	€1,574,000
Based on a 5 year build up for benefits, a 2 year build up for uptake of cycling, and an assessment period of 10 years:			
Average annual benefit over 10 years is:	€3,708,000	€8,964,000	€19,616,000
Total benefits over 10 years are:	€37,080,000	€89,640,000	€196,163,000
The maximum annual benefit reached by this level of cycling, per year, is:	€5,335,000	€12,898,000	€28,225,000
This level of benefit is realised in year 7 when both health benefits and uptake of cycling have reached the maximum levels.			
When future benefits are discounted by 5 % per year:			
Current value of the average annual benefit, averaged across 10 years is:	€2,669,000	€6,453,000	€14,122,000
The current value of the total benefits accumulated over 10 years is:	€26,695,000	€64,534,000	€141,222,000
Benefit–Cost Ratio			
The total costs of:	€12,000,000	€12,000,000	€12,000,000
Total savings over 10 years of:	€26,695,000	€64,534,000	€141,222,000
Assuming 5 year build up of benefits, 2 years build up of uptake, discounting 5 % per year			
The benefit to cost ratio is therefore:	**2.22:1**	**5.38:1**	**11.77:1**

The HEAT analysis was also performed on the predicted group from the stated preference survey alone where approximately 50% was to switch commute travel mode. This predicted group led to a benefit cost ratio of over 45:1, and over 10 years, would produce approximately €500,000,000 in health benefits. From reviewing other economic appraisals of cycling facilities it is known that a figure of this level is extremely unusual and to utilize this figure in the appraisal of the route would be inaccurate.

7.6 Discussion

It can be seen that based solely on the increase in cycling for commuting, and not factoring in the increase in cycling for leisure and other purposes, the proposed cycle route could have a positive impact on the health of the local population. From a National Travel Survey carried out by Central Statistics office of Ireland in 2009, it is known that 25% of all trips undertaken in Ireland are for commuting purposes. Therefore, one can see how the increased rate of cycling along the proposed cycle route will most likely be much greater than that factored into the analysis.

The author believes the modal switch figure of 2.5% would be very achievable in this area and could be considered a conservative value for the modal switch in the area. As mentioned previously, the current cycling rate in the study area is 1.72%, and the national cycling rate is 2.2%. The gap of 0.5% demonstrates that there is scope for growth in this category in the area. An investment such as the proposed cycle route could act as a catalyst for a major increase in cycling in the area as people discover this mode of transport.

The benefit cost ratios are very good for an investment in transport. For public transport projects, benefit cost ratios tend to hover between 1 and 1.5. It can be seen that the construction of a tram extension that is presently underway (Luas BXD) had a benefit cost ratio of 1.26:1 (Rail Procurement Agency, 2009), and that the construction of a metro line (Metro North) in Dublin City had a benefit cost ratio of 1.46:1 (Rail Procurement Agency, 2010). Both these public transport projects are considered to be worthwhile. These ratios would usually be for much larger investments but would still be considered worthwhile. Presently, investment in cycling facilities in Ireland is very low. Larger investments in cycle facilities are very rare. However, from the HEAT analysis, it is apparent that these larger investments would be very worthwhile.

As seen in the case study of the Great Western Greenway in Mayo, the present usage far exceeded the expectation of the stakeholders involved. The usage arises from locals and non-locals utilising the infrastructure and has led to increased economic activity in the area.

The economic benefits to the local area solely from increased tourism has led to the creation of many new jobs and has helped protect many other jobs that might have otherwise been lost with the prevailing economic conditions in Ireland.

If the proposed cycle route was constructed, it would most likely generate the same economic activity with non-locals and locals using it. As the route commences in the country's largest tourist destination, and passes through many scenic locations, it is believed that this cycle route could become a very popular tourist facility as well as being a convenient facility for both commuters and leisure users. The proposed facility passes within 1km of two of the Ireland's largest employers, and also a university, therefore the potential scope for usage is very high.

7.7 Conclusions

From the previous analysis it can be deduced that if the cycle route was constructed along the canal towpath, the economic health benefits from present day non cycling commuters switching their travel mode for commuting to cycling, would reduce their mortality rate as a group by 18%. It was investigated how if the modal share of cycling was to increase from 1.72% to 2.5%, 5% and 10% would impact the health of the population in the study area. The increase in cycling rates would reduce the number of deaths per year by between 3.39 and 17.93, depending on the modal switch. Using the European Union's statistical value of life at €1,574,000, it can be inferred that over a 10 year period with a 2 year uptake of cycling and 5 years for the build-up of the health benefits, that the benefits accumulated over 10 years would be between €26 million and €141 million, dependent on the modal switch. These benefits would results from an initial investment of €12 million. This would lead to benefit cost ratios of between 2.22:1 and 11.77:1, dependent on the mode switch. For a transport facility, the ratios are very favourable and indicate that this would be a very worthwhile infrastructure project for the area.

When one considers the economic benefits from the Great Western Greenway case study, it becomes apparent how valuable this piece of proposed infrastructure could be to the area. Many would benefit both in terms of health and well being, and many would benefit economically, with increased business from new tourism and increased productivity from better health.

8 Overall Benefits

This chapter compiles the results of the findings from the previous analysis chapters and completes an overall examination of the cycle route planned in the study area.

8.1 Introduction

Within Chapters 3, 6 and 7 presented several key pieces of analysis. In the case study, the success of a greenway in Ireland was tested with sensitivity analysis, in relation to usage and tourists' spend in the area. It was desired that this sensitivity analysis could be extended beyond just what tourists spent in the local area, and that it would address the benefits derived by commuters and recreational users. In the stated preference analysis, the willingness to pay of commuters, the recreational users, and the tourists was identified. Identifying the willingness to pay of these groups was fundamental to calculating the value and benefit derived by these groups, from different types of cycling infrastructure. This willingness to pay could be used in identifying what value these different groups would derive from the proposed cycling infrastructure, in the study area. The health economic analysis demonstrated that the health economic benefits accrued from increased cycling in the study area alone, could justify the construction of the cycle route in the area. However, it is still vital that the other benefits of the construction of the cycle route be included in this analysis.

8.2 Methodology

It was concluded that the analysis from the three previous analysis chapters should be combined into one method of analysis, and performed on the study area. This method of analysis was performed on a segregated cycling facility and an on-road cycle lane option for the proposed cycle route. For this single method of analysis, there were several assumptions necessary. The Department of Transport and Department of Finance guidelines were used for development of this analysis (Department of Transport, 2009, Department of Finance 2009).

It was decided that several levels of usage would be tested. It was decided that the annual usage levels would range from 100,000 per annum to 1,000,000 per annum. The figures chosen are believed to represent the range of potential usage within the study area. From the case study of the Great Western Greenway, it was identified that the usage level was more than 100,000 per annum. This is in an area with a population of more than 5,000. The population of the study area is over 140,000, and hence, the potential usage levels could be much higher. Within these levels, the usage would be spread across the three categories of users. The usage levels used in the analysis of the study area can be viewed in Table 8-1. The analysis in this study would be conducted over a ten year period, and the usage would remain constant over this time.

From the Quarterly National Housing Survey by the Central Statistics Office (Central Statistics Office, 2009) it is known that 25% of all trips undertaken in Ireland, are for commute purposes. Ergo, for the analysis conducted on the study area, 25% of all trips were assumed to be for commute purposes. Following on from this, it was decided to allow recreational trips to account for 50% of the usage and tourist related trips to account for 25%. The usage levels for the different categories of users can be viewed in Table 8-1.

Table 8-1 Levels of Usage

Usage Level:	100,000	250,000	500,000	1,000,000
25% Commuters:	25,000	62,500	125,000	250,000
50% Recreational:	50,000	125,000	250,000	500,000
25% Tourists:	25,000	62,500	125,000	250,000

Various assumptions were required for this analysis, in relation to distances and times. It was decided to utilise the distances and the days per year cycled by those presently cycling from the stated preference survey, in calculating the HEAT benefits for commuters. This resulted in the assumption that the average commute distance for the analysis was 8km, and the days cycled per year were 48 days. As mentioned in Chapter 6, and Chapter 7, information pertaining to cycling for recreational purposes and tourist purposes is presently very restricted. It was decided to utilise conservative values for the distances cycled, and the days spent cycling. It was deduced that a distance of 5km for recreational and tourist trips would be appropriate and the number of days spent cycling was calculated at 156 days (three days per week). It was decided to perform HEAT analysis on just the commuters and recreational groups, as these were habitual users and therefore would derive greater health benefits from increased exercise, whereas tourists were one off users and therefore would not derive the same benefits from repeated exercise along the cycle route. Any benefits that tourists would derive from using the cycleway would also be realised in their country of residence.

The willingness to pay of the groups was calculated in minutes. In order to determine the willingness to pay of the various groups, the time for the trips was required. The distances that the various groups were cycling were already determined. It was assumed that the average speed of cyclists was 30km/hr, and from this, the time travelled over the distances that the groups covered was identified. The times used for calculating the willingness to pay of the groups can be viewed in Table 8-2.

Table 8-2 Times Used for Willing to Pay

Group	Speed	Distance of Trip	Time Cycling
Commuters	30 km/hr	8 km	16 minutes
Recreational Users	30 km/hr	5 km	10 minutes
Tourists	30 km/hr	5 km	10 minutes

From the case study in Chapter 3, it is known that tourists spend on average €49.85 per day while cycling in Ireland (Fitzpatricks, 2011). This figure was used for calculating the total expenditure by the tourist group, in the analysis at the various usage levels.

The estimation of the costs of the construction of the cycle route was the same as outlined in Chapter 7. The figure used in the health economic study was €12,000,000. The cost of construction is estimated to be the same for the segregated cycling facility and the cycle lane along the road. The time frame over which the investment would be evaluated was chosen as 10 years. The time period was selected as it was conservative estimate of when investment might be required in the proposed cycle route. It is believed that the route would longer life expectancy than 10 years, but after this time period there may be some additional investment required.

Having determined the assumptions and values necessary for calculating the benefits and costs, the analysis could then commence. This combined methodology was first performed on the on-road cycle lane option in the study area and on the segregated cycling facility. The differences in the results of the two options could then be more readily identified.

8.1 Analysis – On-Road Cycle Lane

This section presents the analysis that was completed on all the usage levels outlined in Section 8.2 on an on-road cycle lane in the study area and results in a benefit cost ratio for each of the usage levels, and the different cycling infrastructure levels.

8.1.1 Usage Level of 100,000 Per Annum

This section completes a cost benefit appraisal including the health economic results, willingness to pay and the tourist spend in the area over a ten year period, where the usage level of the cycle route is assumed to be 100,000 per annum for an on-road cycle lane.

Table 8-3 outlines the results of a cost benefit appraisal performed on the usage level of 100,000 per annum. It can be seen that over a 10 year period, that the total benefits minus the costs are €4,740,500. This is the discounted future value which takes inflation at a 5% level into account, as recommended by the Department of Finance (Department of Finance, 2011). It can be observed in Table 8-3 that the resultant cost benefit ratio is 1.42:1. It can be seen in the analysis that the expenditure by the tourists, relative to the other benefits, is much larger and accounts for nearly 50% of the benefits. It was decided to examine the benefits without the expenditure by tourists. These results can also be seen in Table 8-3. It can be observed from this analysis without the tourist spend, that the benefit cost ratio is 0.66:1, and the total benefits minus the costs (taking inflation of 5% per annum into account) is -€7,098,875. This indicates that when discounting expenditure by tourists and using the value of 100,000 users per annum, the project would not be worthwhile. The benefit cost ratio of 1.42:1 indicates that for every €1 that was invested in the cycle route, there would be a return of €1.42 on the investment. However, for the benefit cost ratio of 0.39:1, for every €1 that was invested, there would only be a return of €0.39 on the investment, indicating that there would be a loss of €0.61 for every €1 invested.

The usage level of 100,000 per annum would be achievable for the cycle lane. This level of usage would equate to 274 users per day. The on-road cycle lane would be very different in nature to the Great Western Greenway, and probably would not attract as many recreational and tourist users as a fully segregated facility. A fully segregated facility enhances the perception of safety while cycling and therefore would also attract many more commuters than an on-road cycle lane. It is believed that the on-road cycle lane would most likely attract between 100,000 and 250,000 users.

Table 8-3 Usage Level of 100,000 along Cycle Lane with Tourist Spend

Greenway in Study Area											
Usage Per Annum:		**100,000**									
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	**Total**
Total Annual Usage	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	**1,000,000**
Costs:											
Construction	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	**€12,000,000**
Benefits:											
Health Economic Benefits:											
Commuters	€271,000	€271,000	€271,000	€271,000	€271,000	€271,000	€271,000	€271,000	€271,000	€271,000	**€2,710,000**
Recreational	€170,000	€170,000	€170,000	€170,000	€170,000	€170,000	€170,000	€170,000	€170,000	€170,000	**€1,700,000**
Expenditure by Tourists											
Spend:	€1,246,250	€1,246,250	€1,246,250	€1,246,250	€1,246,250	€1,246,250	€1,246,250	€1,246,250	€1,246,250	€1,246,250	**€12,462,500**
Willingness to Pay:											
Commuters	€4,500	€4,500	€4,500	€4,500	€4,500	€4,500	€4,500	€4,500	€4,500	€4,500	**€45,000**
Recreational	€5,000	€5,000	€5,000	€5,000	€5,000	€5,000	€5,000	€5,000	€5,000	€5,000	**€50,000**
Tourists	€2,250	€2,250	€2,250	€2,250	€2,250	€2,250	€2,250	€2,250	€2,250	€2,250	**€22,500**
Total Benefits	€1,699,000	€1,699,000	€1,699,000	€1,699,000	€1,699,000	€1,699,000	€1,699,000	€1,699,000	€1,699,000	€1,699,000	**€16,990,000**
Total Benefits Minus Costs	€499,000	€499,000	€499,000	€499,000	€499,000	€499,000	€499,000	€499,000	€499,000	€499,000	**€4,990,000**
5% Discount	€24,950	€24,950	€24,950	€24,950	€24,950	€24,950	€24,950	€24,950	€24,950	€24,950	**€249,500**
Net Present Value	€474,050	€474,050	€474,050	€474,050	€474,050	€474,050	€474,050	€474,050	€474,050	€474,050	**€4,740,500**
Benefit Cost Ratio											
Total Benefits/Total Costs Including Tourist Spend:			**1.42**		**Net Present Value Including Tourist Spend:**					**€4,740,500**	
Total Benefits/Total Costs Excluding Tourist Spend:			**0.39**		**Total Benefits/Total Costs Excluding Tourist Spend:**					**-€7,846,125**	

8.1.2 Usage Level of 250,000 Per Annum

This section completes a cost benefit appraisal including the health economic results, willingness to pay and the tourist spend in the area over a ten year period, when the usage level of the cycle route is assumed to be 250,000 per annum for an on-road cycle lane.

Table 8-4 outlines the results of a cost benefit appraisal performed on the usage level of 250,000 per annum. It can be seen that over a 10 year period, that the total benefits minus the costs are €28,956,000. This is the discounted future value which takes inflation at a 5% level into account. It can be observed in Table 8-4 that the resultant cost benefit ratio is 3.54:1. As was seen in the examination of the usage level of 100,000, the spend by the tourists, relative to the other benefits, is much larger and accounts for nearly 50% of the benefits. Cost appraisal without the expenditure by the tourists can also be viewed in Table 8-4. It can be observed from the analysis without the tourist spend, that the benefit cost ratio is 0.94:1, and the total benefits minus the costs (taking inflation into account) is €7,509,000. This indicates that using the value of 250,000 users per annum, and when including the expenditure by tourists, that an on-road cycle would be worthwhile. The benefit cost ratio of 3.54:1 indicates that for every €1 that was invested in the cycle route, there would be a return of €3.54 on the investment. However, for the benefit cost ratio 0.94:1, for every €1 that was invested in the cycle route, there would be a return of €0.94 on the investment, resulting in a loss of €0.06 for €1 invested.

The usage level of 250,000 per annum could be an achievable value for the area for an on-road cycle lane. This level of usage would equate to 685 users per day. As mentioned in Section 8.4.1, an on-road cycle lane would most likely not attract as many users as a cycling facility which is fully segregated from traffic. A fully segregated facility enhances the perception of safety while cycling and therefore would attract many more users than an on-road cycle lane. It is believed that the on-road cycle lane would most likely attract between 100,000 and 250,000 users per annum. Therefore, the results in this section would most likely be the approximately the best that could be expected.

Table 8-4 Usage Level of 250,000 along Cycle Lane with Tourist Spend

Greenway in Study Area											
Usage Per Annum:		**250,000**									
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	**Total**
Total Annual Usage	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	**2,500,000**
Costs:											
Construction	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	**€12,000,000**
Benefits:											
Health Economic Benefits:											
Commuters	€679,000	€679,000	€679,000	€679,000	€679,000	€679,000	€679,000	€679,000	€679,000	€679,000	**€6,790,000**
Recreational	€424,000	€424,000	€424,000	€424,000	€424,000	€424,000	€424,000	€424,000	€424,000	€424,000	**€4,240,000**
Expenditure by Tourists:											
Spend by Tourists:	€3,115,625	€3,115,625	€3,115,625	€3,115,625	€3,115,625	€3,115,625	€3,115,625	€3,115,625	€3,115,625	€3,115,625	**€31,156,250**
Willingness to Pay:											
Commuters	€11,250	€11,250	€11,250	€11,250	€11,250	€11,250	€11,250	€11,250	€11,250	€11,250	**€112,500**
Recreational	€12,500	€12,500	€12,500	€12,500	€12,500	€12,500	€12,500	€12,500	€12,500	€12,500	**€125,000**
Tourists	€5,625	€5,625	€5,625	€5,625	€5,625	€5,625	€5,625	€5,625	€5,625	€5,625	**€56,250**
Total Benefits	€4,248,000	€4,248,000	€4,248,000	€4,248,000	€4,248,000	€4,248,000	€4,248,000	€4,248,000	€4,248,000	€4,248,000	**€42,480,000**
Total Benefits Minus Costs	€3,048,000	€3,048,000	€3,048,000	€3,048,000	€3,048,000	€3,048,000	€3,048,000	€3,048,000	€3,048,000	€3,048,000	**€30,480,000**
5% Discount	€152,400	€152,400	€152,400	€152,400	€152,400	€152,400	€152,400	€152,400	€152,400	€152,400	**€1,524,000**
Net Present Value	€2,895,600	€2,895,600	€2,895,600	€2,895,600	€2,895,600	€2,895,600	€2,895,600	€2,895,600	€2,895,600	€2,895,600	**€28,956,000**
Benefit Cost Ratio											
Total Benefits/Total Costs Including Tourist Spend:			**3.54**			**Net Present Value Including Tourist Spend:**				**€28,956,000**	
Total Benefits/Total Costs Excluding Tourist Spend:			**0.94**			**Net Present Value Excluding Tourist Spend:**				**-€710,063**	

8.1.3 Usage Level of 500,000 Per Annum

This section completes a cost benefit appraisal including the health economic results, willingness to pay and the tourist spend in the area over a ten year period, when the usage level of the cycle route is assumed to be 500,000 per annum for an on-road cycle lane.

Table 8-5 outlines the results of a cost benefit appraisal performed on the usage level of 500,000 per annum. It can be seen that over a 10 year period, that the total benefits minus the costs are €69,321,500. This is the discounted future value which takes inflation at a 5% level into account. It can be observed in Table 8-5 that the resultant cost benefit ratio is 7.08:1. It can be seen in the analysis that the expenditure by tourists is again, relative to the other benefits, much larger and accounts for nearly 50% of the benefits. Analysis without the expenditure by tourists can also be seen in Table 8-5. It can be observed from the analysis without the tourist spend, that the benefit cost ratio is 1.89:1, and the total benefits minus the costs (taking inflation into account) is €10,124,625. This indicates that when using the value of 500,000 users per annum, and discounting the expenditure by tourists, that the project is worthwhile. The benefit cost ratio of 7.08:1 indicates that for every €1 that was invested in the cycle route, there would be a return of €7.08 on the investment. Similarly, for the benefit cost ratio 1.89:1, for every €1 that was invested in the cycle route, there would be a return of €1.89 on the investment.

The usage level of 500,000 per annum is not believed to be realistic for the area for an on-road cycle. This level of usage would equate to 1,340 users per day. This level of usage would most likely only be attainable under conditions where cycling policy in Ireland would undergo extensive change and result in very high levels of cycling all over Ireland. This level of cycling would result from not just the provision of the new cycle infrastructure in the study area, but also from the introduction of other key improvements to cycling infrastructure and policies.

Table 8-5 Usage Level of 500,000 along Cycle Lane with Tourist Spend

Greenway in Study Area											
Usage Per Annum:		**500,000**									
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	**Total**
Total Annual Usage	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	**5,000,000**
Costs:											
Construction	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	**€12,000,000**
Benefits:											
Health Economic Benefits:											
Commuters	€1,359,000	€1,359,000	€1,359,000	€1,359,000	€1,359,000	€1,359,000	€1,359,000	€1,359,000	€1,359,000	€1,359,000	**€13,590,000**
Recreational	€848,000	€848,000	€848,000	€848,000	€848,000	€848,000	€848,000	€848,000	€848,000	€848,000	**€8,480,000**
Expenditure by Tourists											
Spend by Tourists:	€6,231,250	€6,231,250	€6,231,250	€6,231,250	€6,231,250	€6,231,250	€6,231,250	€6,231,250	€6,231,250	€6,231,250	**€62,312,500**
Willingness to Pay:											
Commuters	€22,500	€22,500	€22,500	€22,500	€22,500	€22,500	€22,500	€22,500	€22,500	€22,500	**€225,000**
Recreational	€25,000	€25,000	€25,000	€25,000	€25,000	€25,000	€25,000	€25,000	€25,000	€25,000	**€250,000**
Tourists	€11,250	€11,250	€11,250	€11,250	€11,250	€11,250	€11,250	€11,250	€11,250	€11,250	**€112,500**
Total Benefits	€8,497,000	€8,497,000	€8,497,000	€8,497,000	€8,497,000	€8,497,000	€8,497,000	€8,497,000	€8,497,000	€8,497,000	**€84,970,000**
Total Benefits - Costs	€7,297,000	€7,297,000	€7,297,000	€7,297,000	€7,297,000	€7,297,000	€7,297,000	€7,297,000	€7,297,000	€7,297,000	**€72,970,000**
5% Discount	€364,850	€364,850	€364,850	€364,850	€364,850	€364,850	€364,850	€364,850	€364,850	€364,850	**€3,648,500**
Net Present Value	€6,932,150	€6,932,150	€6,932,150	€6,932,150	€6,932,150	€6,932,150	€6,932,150	€6,932,150	€6,932,150	€6,932,150	**€69,321,500**
Benefit Cost Ratio											
Total Benefits/Total Costs Including Tourist Spend:			**7.08**			**Net Present Value Including Tourist Spend:**			**€69,321,500**		
Total Benefits/Total Costs Excluding Tourist Spend:			**1.89**			**Net Present Value Excluding Tourist Spend:**			**€10,124,625**		

8.1.4 Usage Level of 1,000,000 Per Annum

This section completes a cost benefit appraisal including the health economic results, willingness to pay and the tourist spend in the area over a ten year period when the usage level of the cycle route is assumed to be 1,000,000 per annum for an on-road cycle lane.

Table 8-6 outlines the results of a cost benefit appraisal performed on the usage level of 1,000,000 per annum. It can be seen that over a 10 year period, that the total benefits minus the costs are €150,033,500. This is the discounted future value which takes inflation at a 5% level into account. It can be observed in Table 8-6 that the resultant cost benefit ratio is 14.16:1. It can be seen in the analysis that spend by the tourists, relative to the other benefits, is much larger and accounts for nearly 50% of the benefits. The analysis without the expenditure by tourists can also be viewed in Table 8-6. It can be observed from the analysis without the tourist spend, that the benefit cost ratio is 3.78:1, and the total benefits minus the costs (taking inflation into account) is €31,639,750. This indicates that using the value of 1,000,000 users per annum, and discounting the spend by tourists, that the project is still worthwhile. The benefit cost ratio of 14.16:1 indicates that for every €1 that was invested in the cycle route, there would be a return of €14.16 on the investment. Similarly, for the benefit cost ratio 3.78:1, for every €1 that was invested in the cycle route, there would be a return of €3.78 on the investment.

The usage level of 1,000,000 per annum is believed to be very optimistic for an on-road cycle lane. As mentioned in Section 8.4.3, for an annual usage of above 500,000 per annum, there would most likely need to be large scale improvements in cycling policy and infrastructure outside of this investment in the proposed cycle route. This level of usage would equate to 2,740 users per day. Ireland in the past five years has implemented several important policy issues and introduced improved cycling infrastructure, in several locations. If these improvements were to increase at a large scale, the figure of 1,000,000 users per annum for an on-road cycle lane may be feasible but even then, it may still be optimistic.

Table 8-6 Usage Level of 1,000,000 along Cycle Lane with Tourist Spend

Greenway in Study Area											
Usage Per Annum:		**1,000,000**									
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	**Total**
Total Annual Usage	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	**10,000,000**
Costs:											
Construction	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	**€12,000,000**
Benefits:											
Health Economic Benefits:											
Commuters	€2,717,000	€2,717,000	€2,717,000	€2,717,000	€2,717,000	€2,717,000	€2,717,000	€2,717,000	€2,717,000	€2,717,000	**€27,170,000**
Recreational	€1,696,000	€1,696,000	€1,696,000	€1,696,000	€1,696,000	€1,696,000	€1,696,000	€1,696,000	€1,696,000	€1,696,000	**€16,960,000**
Expenditure by Tourists:											
Spend:	€12,462,500	€12,462,500	€12,462,500	€12,462,500	€12,462,500	€12,462,500	€12,462,500	€12,462,500	€12,462,500	€12,462,500	**€124,625,000**
Willingness to Pay:											
Commuters	€45,000	€45,000	€45,000	€45,000	€45,000	€45,000	€45,000	€45,000	€45,000	€45,000	**€450,000**
Recreational	€50,000	€50,000	€50,000	€50,000	€50,000	€50,000	€50,000	€50,000	€50,000	€50,000	**€500,000**
Tourists	€22,500	€22,500	€22,500	€22,500	€22,500	€22,500	€22,500	€22,500	€22,500	€22,500	**€225,000**
Total Benefits	€16,993,000	€16,993,000	€16,993,000	€16,993,000	€16,993,000	€16,993,000	€16,993,000	€16,993,000	€16,993,000	€16,993,000	**€169,930,000**
Total Benefits - Costs	€15,793,000	€15,793,000	€15,793,000	€15,793,000	€15,793,000	€15,793,000	€15,793,000	€15,793,000	€15,793,000	€15,793,000	**€157,930,000**
5% Discount	€789,650	€789,650	€789,650	€789,650	€789,650	€789,650	€789,650	€789,650	€789,650	€789,650	**€7,896,500**
Net Present Value	€15,003,350	€15,003,350	€15,003,350	€15,003,350	€15,003,350	€15,003,350	€15,003,350	€15,003,350	€15,003,350	€15,003,350	**€150,033,500**
Benefit Cost Ratio											
Total Benefits/Total Costs Including Tourist Spend:			**14.16**				**Net Present Value Including Tourist Spend:**			**€150,033,500**	
Total Benefits/Total Costs Excluding Tourist Spend:			**3.78**				**Net Present Value Excluding Tourist Spend:**			**€31,639,750**	

8.2 Analysis – Segregated Facility

This section presents the analysis that was completed on all the usage levels outlined in Section 8.2 on the segregated cycling facility option for the study area and results in a benefit cost ratio for each of the usage levels, and the different cycling infrastructure levels.

8.2.1 Usage Level of 100,000 Per Annum

This section completes a cost benefit appraisal including the health economic results; willingness to pay and the tourist spend in the area over a ten year period, where the usage level of the cycle route is assumed to be 100,000 per annum a segregated cycling facility.

Table 8-7 outlines the results of a cost benefit appraisal performed on the usage level of 100,000 per annum. It can be seen that over a 10 year period, that the total benefits minus the costs are €5,126,738. This is the discounted future value which takes inflation at a 5% level into account. It can be observed in Table 8-7 that the resultant benefit cost ratio is 1.43:1. It can be seen in the analysis that spend by the tourists, relative to the other benefits, is much larger and accounts for nearly 50% of the benefits. It was decided to examine the benefits without the expenditure by tourists. These results can also be seen in Table 8-7. It can be observed from this analysis without the tourist spend, that the benefit cost ratio is 0.39:1, and the total benefits minus the costs (taking inflation into account) is -€7,273,450. This indicates that when discounting expenditure by tourists and using the conservative value of 100,000 users per annum, that the project would only be worthwhile if the tourist spend transpired. The benefit cost ratio of 1.43:1 indicates that for every €1 that was invested in the cycle route, there would be a return of €1.43 on the investment. However, for the benefit cost ratio 0.39:1, for every €1 that was invested, there would be a return of €0.39, implying that there would be a loss of €0.61 for every €1 invested.

The usage level of 100,000 per annum is believed to be a very conservative value. This analysis could be considered the lowest level of usage expected. This level of usage would equate to 274 users per day. The proposed cycle route would be longer than the Great Western Greenway, and the surrounding area of the proposed cycle route has a population that is 28 times greater than that of the surrounding area of the Great Western Greenway. This indicates that the potential usage of the proposed cycle route would be much greater than that of the Great Western Greenway.

Table 8-7 Usage Level of 100,000 along Greenway with Tourist Spend

Greenway in Study Area											
Usage Per Annum:		**100,000**									
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	**Total**
Total Annual Usage	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	**1,000,000**
Costs:											
Construction	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	**€12,000,000**
Benefits:											
Health Economic Benefits:											
Commuters	€271,000	€271,000	€271,000	€271,000	€271,000	€271,000	€271,000	€271,000	€271,000	€271,000	**€2,710,000**
Recreational	€170,000	€170,000	€170,000	€170,000	€170,000	€170,000	€170,000	€170,000	€170,000	€170,000	**€1,700,000**
Expenditure by Tourists:											
Spend:	€1,246,250	€1,246,250	€1,246,250	€1,246,250	€1,246,250	€1,246,250	€1,246,250	€1,246,250	€1,246,250	€1,246,250	**€12,462,500**
Willingness to Pay:											
Commuters	€5,250	€5,250	€5,250	€5,250	€5,250	€5,250	€5,250	€5,250	€5,250	€5,250	**€52,500**
Recreational	€18,000	€18,000	€18,000	€18,000	€18,000	€18,000	€18,000	€18,000	€18,000	€18,000	**€180,000**
Tourists	€4,750	€4,750	€4,750	€4,750	€4,750	€4,750	€4,750	€4,750	€4,750	€4,750	**€47,500**
Total Benefits	€1,715,250	€1,715,250	€1,715,250	€1,715,250	€1,715,250	€1,715,250	€1,715,250	€1,715,250	€1,715,250	€1,715,250	**€17,152,500**
Total Benefits Minus Costs	€515,250	€515,250	€515,250	€515,250	€515,250	€515,250	€515,250	€515,250	€515,250	€515,250	**€5,152,500**
5% Discount	€2,576	€2,576	€2,576	€2,576	€2,576	€2,576	€2,576	€2,576	€2,576	€2,576	**€25,763**
Net Present Value	€512,674	€512,674	€512,674	€512,674	€512,674	€512,674	€512,674	€512,674	€512,674	€512,674	**€5,126,738**
Benefit Cost Ratio:											
Total Benefits/Total Costs Including Tourist Spend:			**1.43**				**Net Present Value Including Tourist Spend:**			**€5,126,738**	
Total Benefits/Total Costs Excluding Tourist Spend:			**0.39**				**Net Present Value Excluding Tourist Spend:**			**-€7,273,450**	

8.2.2 Usage Level of 250,000 Per Annum

This section completes a cost benefit appraisal including the health economic results; willingness to pay and the tourist spend in the area over a ten year period, when the usage level of the cycle route is assumed to be 250,000 per annum for a segregated cycling facility.

Table 8-8 outlines the results of a cost benefit appraisal performed on the usage level of 250,000 per annum. It can be seen that over a 10 year period, that the total benefits minus the costs are €29,341,938. This is the discounted future value which takes inflation at a 5% level into account. It can be observed in Table 8-8 that the resultant benefit to cost ratio cost is 3.57:1. As was seen in the examination of the usage level of 100,000, the expenditure by the tourists, relative to the other benefits, is much larger and accounts for nearly 50% of the benefits. It was decided to examine the benefits without the expenditure by tourists and can be also seen in Table 8-8. It can be observed from the analysis without the tourist spend, that the benefit cost ratio is 2.57:1, and the total benefits minus the costs (taking inflation into account) is -€266,500. This indicates that using the value of 250,000 users per annum, and when including the expenditure by tourists, that the project is worthwhile. The benefit cost ratio of 3.57:1 indicates that for every €1 that was invested in the cycle route, there would be a return of €3.57 on the investment. However, for the benefit cost ratio 0.98:1, for every €1 that was invested in the cycle route, there would be a return of €0.98 on the investment, and therefore a loss of €0.02 for €1 invested.

The usage level of 250,000 per annum is believed to be a very achievable value for the area for a segregated cycling facility. This analysis could be considered to be readily attainable. This level of usage would equate to 685 users per day. As mentioned in Section 8.3.1, the proposed cycle route would be longer than the Great Western Greenway, at 60km long, and the surrounding area of the proposed cycle route has a population that is 28 times greater than that of the surrounding area of the Great Western Greenway. This indicates that the potential usage of a segregated cycling facility along the proposed route would be much greater than that of the Great Western Greenway.

Table 8-8 Usage Level of 250,000 along Greenway with Tourist Spend

Greenway in Study Area											
Usage Per Annum:		**250,000**									
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	**Total**
Total Annual Usage	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	**2,500,000**
Costs:											
Construction	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	**€12,000,000**
Benefits:											
Health Economic Benefits:											
Commuters	€679,000	€679,000	€679,000	€679,000	€679,000	€679,000	€679,000	€679,000	€679,000	€679,000	**€6,790,000**
Recreational	€424,000	€424,000	€424,000	€424,000	€424,000	€424,000	€424,000	€424,000	€424,000	€424,000	**€4,240,000**
Expenditure by Tourists											
Spend:	€3,115,625	€3,115,625	€3,115,625	€3,115,625	€3,115,625	€3,115,625	€3,115,625	€3,115,625	€3,115,625	€3,115,625	**€31,156,250**
Willingness to Pay:											
Commuters	€13,125	€13,125	€13,125	€13,125	€13,125	€13,125	€13,125	€13,125	€13,125	€13,125	**€131,250**
Recreational	€45,000	€45,000	€45,000	€45,000	€45,000	€45,000	€45,000	€45,000	€45,000	€45,000	**€450,000**
Tourists	€11,875	€11,875	€11,875	€11,875	€11,875	€11,875	€11,875	€11,875	€11,875	€11,875	**€118,750**
Total Benefits	€4,288,625	€4,288,625	€4,288,625	€4,288,625	€4,288,625	€4,288,625	€4,288,625	€4,288,625	€4,288,625	€4,288,625	**€42,886,250**
Total Benefits Minus Costs	€3,088,625	€3,088,625	€3,088,625	€3,088,625	€3,088,625	€3,088,625	€3,088,625	€3,088,625	€3,088,625	€3,088,625	**€30,886,250**
5% Discount	€154,431	€154,431	€154,431	€154,431	€154,431	€154,431	€154,431	€154,431	€154,431	€154,431	**€1,544,313**
Net Present Value	€2,934,194	€2,934,194	€2,934,194	€2,934,194	€2,934,194	€2,934,194	€2,934,194	€2,934,194	€2,934,194	€2,934,194	**€29,341,938**
Benefit Cost Ratio											
Total Benefits/Total Costs Including Tourist Spend:			**3.57**				**Net Present Value Including Tourist Spend:**			**€29,341,938**	
Total Benefits/Total Costs Excluding Tourist Spend:			**0.98**				**Net Present Value Excluding Tourist Spend:**			**-€266,500**	

8.2.3 Usage Level of 500,000 Per Annum

This section completes a cost benefit appraisal including the health economic results, willingness to pay and the tourist spend in the area over a ten year period, when the usage level of the cycle route is assumed to be 500,000 per annum for a segregated cycling facility.

Table 8-9 outlines the results of a cost benefit appraisal performed on the usage level of 500,000 per annum. It can be seen that over a 10 year period, that the total benefits minus the costs are €68,181,875. This is the discounted future value which takes inflation at a 5% level into account. It can be observed in Table 8-9 that the resultant benefit cost ratio is 7.15:1. It can be seen in the analysis that the expenditure by tourists is again, relative to the other benefits, much larger and accounts for nearly 50% of the benefits. The analysis without the expenditure by tourists can also be seen Table 8-9. It can be observed from the analysis without the tourist spend, that the benefit cost ratio is 1.96:1, and the total benefits minus the costs (taking inflation into account) is €5,869,375. This indicates that when using the value of 500,000 users per annum, and discounting the expenditure by tourists, that the project is still worthwhile. The benefit cost ratio of 7.15:1 indicates that for every €1 that was invested in the cycle route, there would be a return of €7.15 on the investment. Similarly, for the benefit cost ratio 1.96:1, for every €1 that was invested in the cycle route, there would be a return of €1.96 on the investment.

The usage level of 500,000 per annum is believed to not be unrealistic for the area. This analysis could be considered to be attainable under the right circumstances (marketing locally and abroad, continued improvement in the cycling rate in Ireland for commuting, etc). This level of usage would equate to 1,340 users per day. The Great Western Greenway sees a very large usage level relative to the size of the local population. This has been achieved by extensive marketing both locally and abroad, along with promotion of the facility for commuting in local schools and employment centres. Therefore, under similar circumstances, the usage level of 500,000 should be achievable.

Table 8-9 Usage Level of 500,000 along Greenway with Tourist Spend

Greenway in Study Area											
Usage Per Annum:		**500,000**									
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	**Total**
Total Annual Usage	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	**5,000,000**
Costs:											
Construction	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	**€12,000,000**
Benefits:											
Health Economic Benefits:											
Commuters	€1,359,000	€1,359,000	€1,359,000	€1,359,000	€1,359,000	€1,359,000	€1,359,000	€1,359,000	€1,359,000	€1,359,000	**€13,590,000**
Recreational	€848,000	€848,000	€848,000	€848,000	€848,000	€848,000	€848,000	€848,000	€848,000	€848,000	**€8,480,000**
Expenditure of Tourists											
Spend:	€6,231,250	€6,231,250	€6,231,250	€6,231,250	€6,231,250	€6,231,250	€6,231,250	€6,231,250	€6,231,250	€6,231,250	**€62,312,500**
Willingness to Pay:											
Commuters	€26,250	€26,250	€26,250	€26,250	€26,250	€26,250	€26,250	€26,250	€26,250	€26,250	**€262,500**
Recreational	€90,000	€90,000	€90,000	€90,000	€90,000	€90,000	€90,000	€90,000	€90,000	€90,000	**€900,000**
Tourists	€23,750	€23,750	€23,750	€23,750	€23,750	€23,750	€23,750	€23,750	€23,750	€23,750	**€237,500**
Total Benefits	€8,578,250	€8,578,250	€8,578,250	€8,578,250	€8,578,250	€8,578,250	€8,578,250	€8,578,250	€8,578,250	€8,578,250	**€85,782,500**
Total Benefits - Costs	€7,378,250	€7,378,250	€7,378,250	€7,378,250	€7,378,250	€7,378,250	€7,378,250	€7,378,250	€7,378,250	€7,378,250	**€73,782,500**
5% Discount	€368,913	€560,063	€560,063	€560,063	€560,063	€560,063	€560,063	€560,063	€560,063	€560,063	**€5,600,625**
Net Present Value	€7,009,338	€6,818,187	€6,818,187	€6,818,187	€6,818,187	€6,818,187	€6,818,187	€6,818,187	€6,818,187	€6,818,187	**€68,181,875**
Benefit Cost Ratio											
Total Benefits/Total Costs Including Tourist Spend:			**7.15**				**Net Present Value Including Tourist Spend:**			**€68,181,875**	
Total Benefits/Total Costs Excluding Tourist Spend:			**1.96**				**Net Present Value Excluding Tourist Spend:**			**€5,869,375**	

8.2.4 Usage Level of 1,000,000 Per Annum

This section completes a cost benefit appraisal including the health economic results, willingness to pay and the tourist spend in the area over a ten year period when the usage level of the cycle route is assumed to be 1,000,000 per annum for a segregated cycling facility.

Table 8-10 outlines the results of a cost benefit appraisal performed on the usage level of 1,000,000 per annum. It can be seen that over a 10 year period, that the total benefits minus the costs are €151,577,250. This is the discounted future value which takes inflation at a 5% level into account. It can be observed in Table 8-10 that the resultant benefit cost ratio is 14.30:1. It can be seen in the analysis that spend by the tourists, relative to the other benefits, is much larger and accounts for nearly 50% of the benefits. The analysis without the expenditure by tourists can be viewed in Table 8-10. It can be observed from the analysis without the tourist spend, that the benefit cost ratio is 10.28:1, and the total benefits minus the costs (taking inflation into account) is €33,183,500. This indicates that using the value of 1,000,000 users per annum, and discounting the expenditure by tourists, that the project is still worthwhile. The benefit cost ratio of 14.30:1 indicates that for every €1 that was invested in the cycle route, there would be a return of €14.30 on the investment. Similarly, for the benefit cost ratio 3.91:1, for every €1 that was invested in the cycle route, there would be a return of €3.91 on the investment.

The usage level of 1,000,000 per annum is believed to be quite optimistic. This analysis could be considered to be attainable, if there were substantial changes in the travel patterns in the country. If the levels of cycling that are seen in The Netherland and Denmark were to occur in Ireland, then this level would be possible. This level of usage would equate to 2,740 users per day. This usage level could be possible, but would require significant improvements elsewhere relating to cycling infrastructure and policy. Ireland in the past five years has implemented several important policy issues and introduced improved cycling infrastructure, in several location. If these improvements were to continue, the figure of 1,000,000 users per annum may change from being optimistic to realistic.

Table 8-10 Usage Level of 1,000,000 along Greenway with Tourist Spend

Greenway in Study Area											
Usage Per Annum:		**1,000,000**									
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	**Total**
Total Annual Usage	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	**10,000,000**
Costs:											
Construction	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	€1,200,000	**€12,000,000**
Benefits:											
Health Economic Benefits:											
Commuters	€2,717,000	€2,717,000	€2,717,000	€2,717,000	€2,717,000	€2,717,000	€2,717,000	€2,717,000	€2,717,000	€2,717,000	**€27,170,000**
Recreational	€1,696,000	€1,696,000	€1,696,000	€1,696,000	€1,696,000	€1,696,000	€1,696,000	€1,696,000	€1,696,000	€1,696,000	**€16,960,000**
Expenditure by Tourists											
Spend:	€12,462,500	€12,462,500	€12,462,500	€12,462,500	€12,462,500	€12,462,500	€12,462,500	€12,462,500	€12,462,500	€12,462,500	**€124,625,000**
Willingness to Pay:											
Commuters	€52,500	€52,500	€52,500	€52,500	€52,500	€52,500	€52,500	€52,500	€52,500	€52,500	**€525,000**
Recreational	€180,000	€180,000	€180,000	€180,000	€180,000	€180,000	€180,000	€180,000	€180,000	€180,000	**€1,800,000**
Tourists	€47,500	€47,500	€47,500	€47,500	€47,500	€47,500	€47,500	€47,500	€47,500	€47,500	**€475,000**
Total Benefits	€17,155,500	€17,155,500	€17,155,500	€17,155,500	€17,155,500	€17,155,500	€17,155,500	€17,155,500	€17,155,500	€17,155,500	**€171,555,000**
Total Benefits - Costs	€15,955,500	€15,955,500	€15,955,500	€15,955,500	€15,955,500	€15,955,500	€15,955,500	€15,955,500	€15,955,500	€15,955,500	**€159,555,000**
5% Discount	€797,775	€797,775	€797,775	€797,775	€797,775	€797,775	€797,775	€797,775	€797,775	€797,775	**€7,977,750**
Net Present Value	€15,157,725	€15,157,725	€15,157,725	€15,157,725	€15,157,725	€15,157,725	€15,157,725	€15,157,725	€15,157,725	€15,157,725	**€151,577,250**
Benefit Cost Ratio											
Total Benefits/Total Costs Including Tourist Spend:			**14.30**			**Net Present Value Including Tourist Spend:**			**€151,577,250**		
Total Benefits/Total Costs Excluding Tourist Spend:			**3.91**			**Net Present Value Excluding Tourist Spend:**			**€33,183,500**		

8.3 Cycle Lane Versus Segregated Facility

In Section 8.4, various usage levels were tested for a segregated cycling facility and an on-road cycle lane. It can be determined that for each usage level tested that the segregated facility produces better benefit cost ratios and therefore greater returns for an investment. All the usage levels and the benefit cost ratios can be viewed in Table 8-11. For instance, it can be seen for a usage level of 250,000 per annum, the benefit cost ratio for the segregated facility with the expenditure of tourists is 3.57:1, and for the cycle lane, it is 3.54:1. Therefore, it can be deduced that the segregated cycling facility produces approximately €0.03 more that the on-road cycle lane for every €1 invested. Therefore, the segregated cycling facility represents a better proposition that then on-road cycle lane.

Table 8-11 Usage Levels and Benefit Cost Ratios

Usage Level	Benefit Cost Ratio Segregated Facility		Benefit Cost Ratio Cycle Lane	
	With Tourist Spend	No Tourist Spend	With Tourist Spend	No Tourist Spend
100,000	1.43:1	0.39:1	1.42:1	0.39:1
250,000	3.57:1	0.98:1	3.54:1	0.94:1
500,000	7.15:1	1.96:1	7.08:1	1.89:1
1,000,000	14.3:1	3.91:1	14.16:1	3.78:1

8.4 Cyclist Values of Time

In the previous analysis the health benefits and willingness to pay for differing sized groups and purposes was estimated. By breaking these values down to an individual basis, it is possible to calculate these values on a per person basis. These values were calculated on a per hour basis and are referenced from the National Roads Authority (2011) value of time of €10.98. These values of time were calculated for the different trip purposes and cycling infrastructure types. It can be seen in Table 8-12 that these new values of time range from €10.98 (for a tourist along a road without cycling infrastructure) to €35.19 (for a recreational cyclist along a segregated cycling facility). As mentioned in Section 8.2, it would not be appropriate to consider the health economic benefits for tourists, and therefore they are zero in Table 8-12. The results make intuitive sense with value of time increasing for cycling infrastructure of a higher quality.

Table 8-12 Cyclist Value of Time

Cyclist Value of Time	Value of Time	WTP /min	WTP /Hour	Health Benefits/hour	New Values of Time
Tourist					
No Cycling Facilities	€10.98	€0.00	€0.00	€0.00	€10.98
On-Road Facilities	€10.98	€0.09	€5.40	€0.00	€16.38
Segregated Cycle Lane	€10.98	€0.19	€11.40	€0.00	€22.38
Recreational					
No Cycling Facilities	€10.98	€0.00	€0.00	€2.61	€13.59
On-Road Facilities	€10.98	€0.10	€6.00	€2.61	€19.59
Segregated Cycle Lane	€10.98	€0.36	€21.60	€2.61	€35.19
Commuter					
No Cycling Facilities	€10.98	€0.00	€0.00	€4.25	€15.23
On-Road Facilities	€10.98	€0.18	€10.80	€4.25	€26.03
Segregated Cycle Lane	€10.98	€0.21	€12.60	€4.25	€27.83
Generic					
No Cycling Facilities	€10.98	€0.00	€0.00	€2.68	€13.66
On-Road Facilities	€10.98	€0.14	€8.40	€2.68	€22.06
Segregated Cycle Lane	€10.98	€0.24	€14.40	€2.68	€28.06

8.5 Discussion

Combining the expenditure of tourists, the willingness to pay of the three groups and the health economic benefits into one methodology, has allowed for most of the benefits derived from the construction of new cycling infrastructure to be assessed. It can be seen in the analysis in this chapter that the segregated cycling facility was preferable to the on-road cycle lane. The segregated cycling facility for the proposed cycle route, even under the most conservative estimate for usage, and excluding the expenditure of the tourists, is still a worthwhile project. The expenditure by the tourists is based on the finding of a report that identified the daily spend of cycling tourists on the Great Western Greenway (Fitzpatricks, 2011). It may be the case that the daily spend of tourists may be too high to be used for the study area, or that only part of the expenditure should be attributed to the cycle route planned. Including and excluding the expenditure of tourists led to benefit cost ratios that favour the planned cycle route. The benefit cost ratios for the usage levels for the segregated cycling facility tested can be observed in Table 8-8.

For the infrastructure under investigation, it is believed that a usage level of between 250,000 and 500,000 could be reasonably expected for a segregated facility. The study area investigated has strong East-West transportation movements. The cycle route proposed would be in the East-West direction in the corridor and could facilitate many of the traffic movements. The population of the study area is over 140,000 and has several urban locations and large scale employers. When the usage levels for the Great Western Greenway are observed relative to the population of the area, it becomes apparent that there is scope for a large level of usage of the planned cycle route. The cycle route planned is also part of Eurovelo Route 2 extending East-West across Europe, connecting Galway to Moscow and many cities in between (EuroVelo, 2013). Therefore, there is scope for this route to become a large tourist attraction for the country, with high numbers of tourists attracted to the country by the scheme. Another reason for selecting the segregated cycling facility over the on-road cycle lane is that it is more likely that the segregated cycling facility would attract more tourists that the on-road cycle lane. Therefore, the expenditure by tourists is more likely to become a reality with the segregated cycling facility than the on-road cycle lane.

If the usage level of between 250,000 and 500,000 were to be realised with the given assumptions in the analysis, then it would be expected that the benefit cost ratio of the planned cycle route for a segregated cycling facility would be in the order of between 3.57:1 and 7.15:1. These benefit cost ratios indicate that the proposed cycle route would be very worthwhile.

It can be seen how a person travelling for different trip purposes upon different infrastructure have different values of time. These values of time make intuitive sense, and also are of similar calculations to those of Börjesson and Eliasson (2012) and Wardman et al (2007). A tourist travelling upon a road without cycling infrastructure has the lowest value of time. This is expected as the tourist does not derive the health benefits estimated for the other groups, and the road without cycling infrastructure would not be the desired choice of most tourists. Recreational cyclists travelling upon a segregated cycling facility have the highest value of time for cycling. This is also expected as most recreational cyclists prefer the segregated cycling infrastructure, and also derive the health benefits from regular cycling.

8.6 Conclusions

The analysis of the case study, stated preference survey, and the health economic assessment were combined into one methodology and used to examine the viability of the proposed cycle route in the study area outlined in Chapter 1. Different usage levels were theorised and estimated.

It was determined that the segregated cycling facility presented the better option rather the on-road cycle lane. It was found that the segregated facility, even under the most conservative estimates for usage, is still worthwhile with the most conservative benefit cost ratio of 1.43:1.

From the case study on the Great Western Greenway, it was observed that the usage level was very high relative to the population of the local area. The authors estimate that a usage level of between 250,000 to 500,000 would not be an unreasonable expectation for a segregated cycling facility along the cycle route. Therefore, it would be expected that the benefit cost ratio of the planned cycle route would be in the order of between 3.57:1 and 7.15:1, making this project very worthwhile. This would lead to the project having a net present value of between €29 million and €68 million. On an initial investment of €12 million, these net present values become very attractive.

The new values of time for transport by bicycle can be seen in Table 8-12. These new values of time will be very beneficial for a researcher conducting analysis into cycling infrastructure. These new values will also be very helpful for any professional investigating potential cycling infrastructure projects.

9 Conclusions

9.1 Introduction

This chapter presents the conclusions drawn from the analysis presented in this thesis. This chapter also highlights the impacts of the research conducted, performs a critical assessment of the research and identifies where further future development could be completed.

9.2 Findings from Analysis

The case study of the Great Western Greenway indicated that there was a very positive and large response to a high quality cycleway segregated from traffic, in the rural area studied. This indicated that there was a latent demand for infrastructure of this particular type, in Ireland.

In the case study, it was estimated that domestic and non-domestic tourists spend approximately €1 million per year, in the local area while visiting. From these figures alone, the facility has a payback period of 6 years.

From the stated preference analysis conducted in this research, it was determined that a tourist is willing to increase their cycling travel time by approximately 100% in order to cycle upon a cycling facility which is fully segregated from traffic, rather than along a road without cycling infrastructure. They are willing to increase their travel time by 40-50% to be able to cycle along a road with a cycle lane, rather than a road without cycling facilities. It was found that a tourist is willing to pay €0.09 for a cycle lane along a road and €0.19 for a segregated cycling facility, in order to avoid a road without any cycling infrastructure.

From the stated preference analysis into recreational cyclists it was concluded that a recreational cyclist is willing to increase their cycling travel time by approximately 200% in order to cycle upon a cycling facility which is fully segregated from traffic, rather than along a road without cycling infrastructure, and are willing to increase their travel time by 32% to be able to cycle along a road with a cycle lane, rather than a road without cycling facilities. It was found that a recreational cyclist is willing to pay €0.10 for a cycle lane along a road and

€0.36 for a segregated cycling facility, in order to avoid a road without any cycling infrastructure.

The analysis into commuters concluded that a commute cyclist is willing to increase their cycling travel time by approximately 110%, in order to cycle upon a cycling facility which is fully segregated from traffic, rather than along a road without cycling infrastructure, and are willing to increase their travel time by 100% to be able to cycle along a road with a cycle lane, rather than a road without cycling facilities. It was found that a commuter is willing to pay €0.18 for a cycle lane along a road and €0.21 for a segregated cycling facility, in order to avoid a road without any cycling infrastructure.

It was determined that a recreational cyclist was willing to pay the most for a segregated cycling facility, followed by a commuter, and the tourist was willing to pay the least. In general, older males were more willing to cycle upon roads without cycling facilities than younger females.

The health economic analysis deduced that if the proposed cycle route was constructed, the benefits accumulated over 10 years would be between €26 million and €141 million dependent on the modal shift. The modal shares analysed were 2.5%, 5% and 10%. The modal shares investigated would reduce the number of deaths per year by between 3.39 and 17.93, depending on the modal switch. These benefits would result from an initial investment of €12 million. This would lead to benefit cost ratios of between 2.22:1 and 11.77:1, dependent upon the modal switch. For a transport facility, the ratios are most favourable, and indicate that this would be a very worthwhile infrastructure project for the area.

The analysis of the case study, stated preference survey, and the health economic assessment were combined to form the overall benefits chapter, and then used to examine the viability of the proposed cycle route in the study area. It was determined that for various usage levels tested that the segregated facility produces better benefit cost ratios, and therefore greater returns for an investment. It can be calculated for a usage level of 250,000 cyclists per annum, the benefit to cost ratio for the segregated facility is 3.57:1, and for the cycle lane, it is 3.54:1. Therefore, the segregated cycling facility represents a much better proposition than the on-road cycle lane. This analysis also produced new cyclist values of time that vary depending upon trip purpose and cycle infrastructure. The values range from €10.98 for a tourist cycling upon a road without cycling infrastructure to €35.19 for a recreational cyclist cycling upon a segregated cycling facility.

9.3 Impact of the Research and Policy Implications

Prior to the research presented in this thesis, there was very little information that related to cycling in rural areas and interurban contexts. The literature pertaining to recreational and tourist cycling was also very restrictive. There was no clear method for evaluating cycling infrastructure, and what methods did exist, were quite ambiguous. This research adds new information to these various categories that will not just benefit others conducting research into cycling, but it also has very practical implications, by providing useful data to professionals seeking to design effective cycling infrastructure.

The analysis of the preferences between different standards of cycling facilities for recreational and tourist trips, has not been completed using a stated preference approach. Previous to this study, the studies that did look at the willingness to pay of individuals for cycling infrastructure types, only looked at urban and commute contexts. This study introduced the willingness to pay of individuals for cycling infrastructure for recreational and tourist cycling, in a rural/interurban context. By conducting analysis between the different cycling infrastructure and the different trip purposes, this research provides a detailed account of the values derived from varying standards of cycling facilities, and how these values are influenced by the environmental factors of weather and gradients. The analysis of the preferences for the different standards of cycling infrastructure is supplemented by, examining how a number of personal demographic attributes impact on the preferences for the differing standards of cycling infrastructure. The analysis of these factors enhances the analysis between choices, and identifies the types of individuals and the factors which impact upon the choice of different standards of cycling infrastructure. The findings from examining which factors impact upon the choice and the benefits derived from different choices of cycling infrastructure, adds to the field of research conducted to date, in examining how different trip purposes influence the choices of cycling infrastructure.

The findings from the stated preference analysis, combined with the health economic analysis and the tourist expenditure analysis led to the development of a more comprehensive method for evaluating cycle infrastructure. Present methods focus on urban and commute cycling, whereas this method takes into consideration tourist and recreational related trips. This new methodology allows many factors to be included (health, tourist expenditure, value derived) into one process, that produces one benefit to cost ratio and a net present value. This new assessment of a proposal including the willingness to pay, health benefits and the expenditure of tourists produces one value, and does not require any extra investigation. These values can be used by professionals in identifying the best projects involving cycling. This was supplemented by the calculation of new cyclist values of time for the different trip purposes for different cycling infrastructure. These new values will prove to be very beneficial to a researcher analysing cycling infrastructure, or a professional evaluating different cycling infrastructure. These new values provide new depth to the area of value of time, as presently, not only is there an issue with a lack of a proper value of time for cyclists in Ireland, but internationally, the values of time for non-commute purposes is very restricted also.

The main focuses of the findings is to provide economic valuation of this information, in the form of willingness to pay amounts, along with health economic amounts. The findings are very beneficial for others completing research into cycling as these can form a base from which other research can grow. These findings will be very useful to people involved in designing cycling infrastructure, as it provides a new tool for measuring the impact of cycling infrastructure, and provides a clear, coherent approach for more effectively designing cycling infrastructure. These resulting amounts from the findings demonstrate the economic benefits which could be accrued by constructing cycling infrastructure. The findings also determine which groups derive the most benefits from the different standards of cycling infrastructure.

9.4 Critical Assessment

Although there are many areas in this thesis that have added to the body of research conducted on the uses and benefits of investing in cycling infrastructure, there are a number of limitations which have been summarised in this section.

The use of the internet as a tool to collect survey responses as expected leads to the argument of bias in the data collected, as not all members of the population under investigation have access to the internet. As discussed in Chapter 4, there were several reasons for choosing the internet as the means for collecting survey responses. These varied from resource considerations for targeting the population of interest, to time constraints. While these considerations have been justified in the thesis, some may argue that the sample collected may not be representative of the population.

The scenarios examined focused upon ascertaining respondents preferences for varying cycling infrastructure, for different trip purposes. The trip purposes examined were for commute, tourist and recreational purposes. It could be argued limiting trip purposes to just three types could be seen as a limitation of the research, in that individuals travelling for purposes outside of these three may have different preferences for cycling infrastructure.

The value of time used for willingness to pay was kept constant for all trip purposes, as at present there is not any value of time for cycling for recreational and tourist purposes. The value of time used was the value of cycling time that was developed for the evaluation of cycling infrastructure, and is used by government agencies for designing cycling infrastructure. It could be argued that the value of time used for determining the willingness to pay for recreational and tourist purposes should be different, however presently there does not exist any value of cycling time that could be used, other than the one utilised.

Stated preference was used to evaluate cycling infrastructure preferences. This approach has been criticised by some, as it examines what individuals say they will do, as opposed to what they actually do. However, given that the cycling infrastructure options under investigation in the study area were not available, the stated preference approach was deemed to be the most suitable method, for examining preference for cycling infrastructure. This conclusion was arrived at after examining many previous research studies in the literature where stated preference methods were used to evaluate hypothetical transport scenarios.

9.5 Areas for Further Research

Possible areas for further research could focus on sampling different sections of the population and changing the scenarios presented to the respondents. The approach used in this thesis could be used to target various sub sections of the population, which may be of particular interest to a researcher or transport planner. Such subsections could include those that are in either primary or post primary education, disadvantaged groups, and the elderly. Using any of these subsections to model the perceptions and the willingness to pay for different cycling infrastructure would provide detailed insights, as to what specific requirements these groups may have.

Further investigation into the values of cycling time for different trip purposes would be very beneficial in the design process for cycling infrastructure. If a proposed infrastructure scheme is specifically catering for a certain cycle trip purpose, the different values of time would allow for the scheme to be designed in a more efficient manner.

Further investigation into how tourist cycle trips are influenced by gender could prove to be beneficial. The gender relationship varied from the tourist model to the other models in the analysis, therefore there may be some more detailed investigation required into how gender differences impact upon cycling for tourist purposes.

Changing the stated preference scenarios examined would be another area for further research. Various different attributes were identified in the literature, so varying the attributes included in the scenarios could produce other relevant results.

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Appendix 1: Executive Summary of Trinity College Dublin Scoping Study

Dublin to Mullingar Cycleway Route

Synthesis Report

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April 2011

1. Introduction

This document has been prepared as part of the Route Selection Report for a cycle route between Dublin and Mullingar. The document outlines the conclusions derived of the route selection report. For in depth analysis, please consult the route selection report.

2. Route Selection Study

For the cycle route between Dublin and Mullingar, there were three options considered for the route. They are as follows:

1. Royal Canal towpath.
2. R148/N4.
3. Hybrid of both routes.

These options are displayed below in Figure 2. The Royal Canal towpath route option and the R148/N4 road route options are displayed in blue and pink respectively.

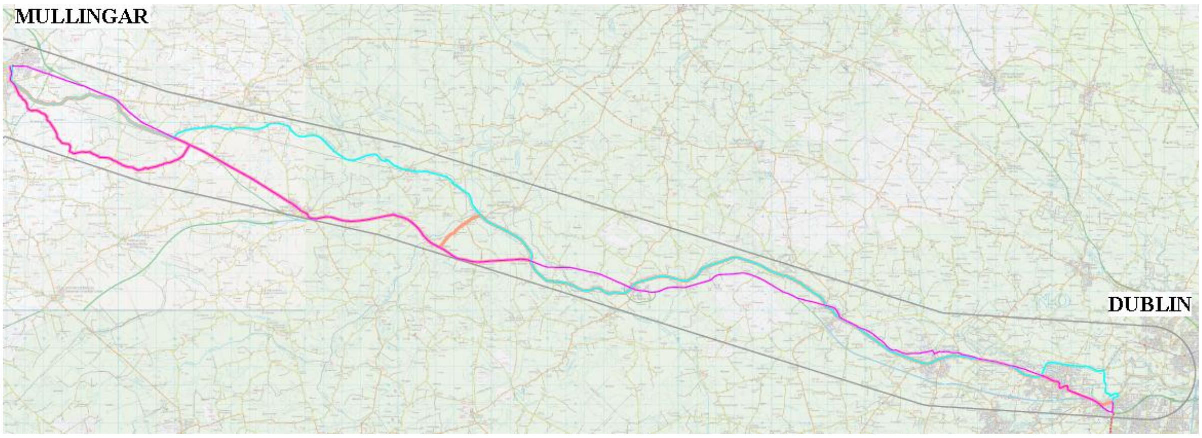

Figure 2: Dublin to Mullingar Corridor with potential options

After research and analysis, it was determined that the most suitable option for a cycle route between Dublin and Mullingar was a hybrid route of both the R148 and the Royal Canal towpath.

Initial research indicated that the best starting/terminating points for the route would be the centre of Lucan village and Moran's Bridge in Mullingar. These two locations were in the centre of large catchment areas and were easily accessible. These locations were beneficial in terms of future expansion of the route at either end. For instance, to the south of the terminus point in Lucan is the present terminus of the Grand Canal Cycle route, and to the north of the terminus point in Mullingar is a greenway through Mullingar that continues to the village of Ballina.

The route was broken down into seven fundamental parts allowing each section to be assessed independently. They are as follows:

- Section 1 Mullingar – McNead's Bridge.
- Section 2 McNead's Bridge – Moyvally.
- Section 3 Moyvally – Enfield.
- Section 4 Enfield – Kilcock.
- Section 5 Kilcock – Maynooth.
- Section 6 Maynooth – Leixlip.
- Section 7 Leixlip – Lucan.
-

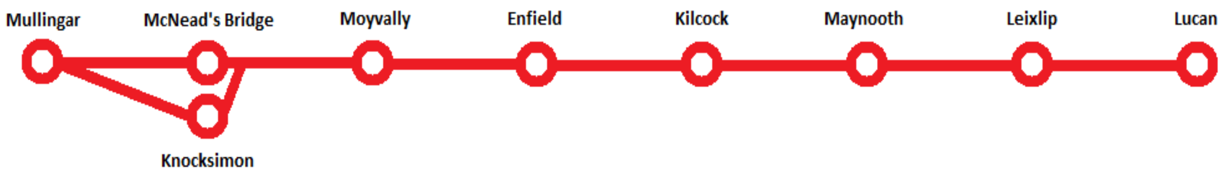

Figure 3: Road Route; Including alternative options for section 1

Figure 4: Canal Route

The Royal Canal towpath and the R148 presented arrays of various advantages and disadvantages in each section. For the Royal Canal Towpath, the advantages and disadvantages are as follows:

<u>Advantages</u>

- Segregation.
- Low traffic level.
- Scenic.
- Canal Towpath already an established recreational route (Royal Canal Way).
- Continuous (Mostly).
- Mostly wide paths and verges.

- Gradients deemed “easy”.[3]
- Path is mostly state owned.
- Good visibility and sightlines (except at bridges).
- Continuation of Greenway in Mullingar and close to Grand Canal Greenway.
- Less junctions.
- More attractive for tourists.
- Approximately 16 – 17% of the towpath is already in use as road/path.

Disadvantages

- Less direct in some locations.
- Isolated.
- Water hazard.
- Ecological impact of construction and increased pedestrians and cyclists along the path.
- Restricted visibility of/from the road, at the Bridges over the canal.
- Fencing required at certain locations where there is no verge.
- Crossing of the R148 at Moyvally.
- Potential cyclist/pedestrian conflict.

For the road (R148/N4) route, the advantages and disadvantages are as follows:

Advantages

- More direct in some instances.
- Long sections of hard shoulder can be converted.
- Not isolated (overlooked by road traffic).
- Directly serves more towns.
- Avails of cycle networks within towns.
- Easily accessible for maintenance, services and emergencies.

Disadvantages

- Discontinuous (hard shoulder ends, no further road space, grass margin available).
- Certain locations where there are bad pinch points (costly removal/upgrade works).
- Potentially very costly due to cost of road realignment and fencing/verge creation.
- Segregation required where speed limit is 80km/hr or above (CROW, 2007).
- High traffic volumes for much of route.
- Many sections of road have vehicles travelling at high speed.
- Many junctions.

[3] This is based on the information provided by Fáilte Ireland (2010) for those interested in walking The Royal Canal Way.

- N4 between McNead’s Bridge and Mullingar upgrade works progressing (possibility of redesignation as motorway or having speed limit increased to 120km/hr).
- High proportion of traffic along route is Heavy Commercial Vehicles (HCVs).
- Poor visibility at many locations.

Utilising existing infrastructure, whilst also focusing on the safety of potential users, was a priority in the selection of the route. On investigation, it was realised that approximately 16-17% of the Royal Canal towpath was either in use as local roads with low traffic volumes or as paved paths. This was beneficial to the project as these areas required the minimum of work. All sections have parts of the towpath paved. This reduced the work necessary to be carried out along the canal route. These existing pieces of infrastructure were ideal in safety terms also, as the interaction with motorised traffic was minimal in relation to the road route option. These sections of infrastructure were also acceptably direct.

The road route varied considerably from section to section, and within each section. For instance, Section 6, the road between Maynooth and Pike Bridge (entrance to the Carton Demesne) is not ideal for a cycle route. The sightlines are poor and the hard shoulder is restricted. However, from Pike Bridge to Leixlip, the road improves greatly. There are wide hard shoulders and visibility is good. There are many sections comparable to this along the entire R148/N4 route. Certain sections require minimal work in terms of upgrade works, however; these sections tend to have one if not a series of pinch points that would entail significant work in order to upgrade. The significant upgrade works along the R148 route range from road widening, junction redesign, bridge alteration, path segregation to possibly compulsory purchase orders.

The preferred route for each section is as follows:

Section 1: Royal Canal Towpath. Route can be seen in blue in Figure 5.

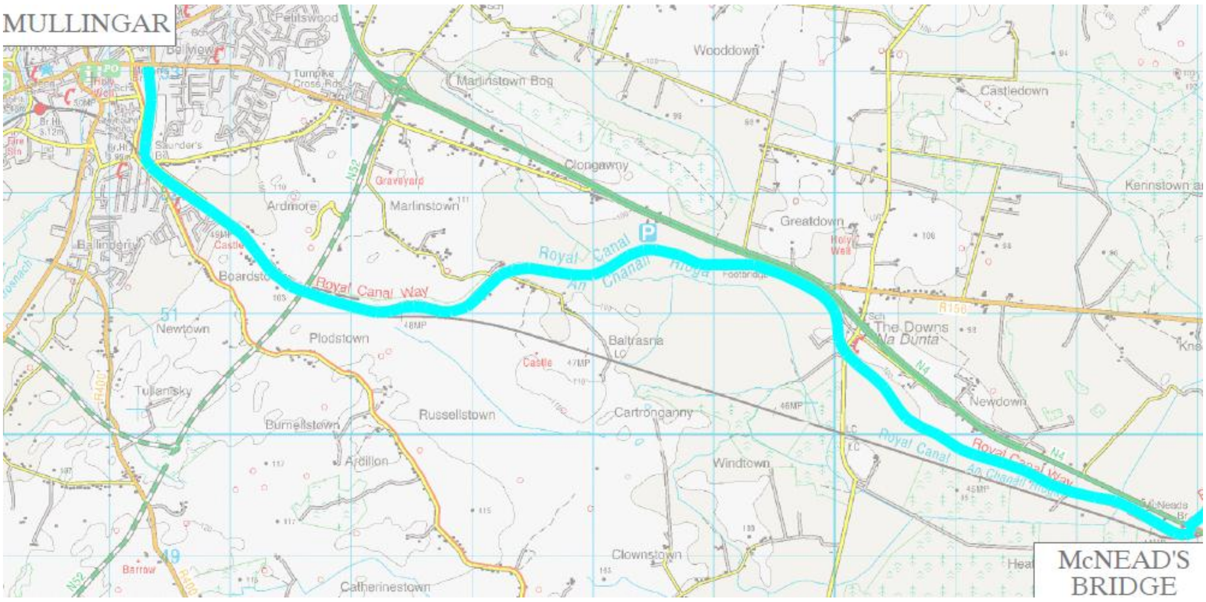

Figure 5: Preferred Route for Section 1 along the Royal Canal Towpath

For Section 2: Royal Canal Towpath. Route can be seen in blue in Figure 6.

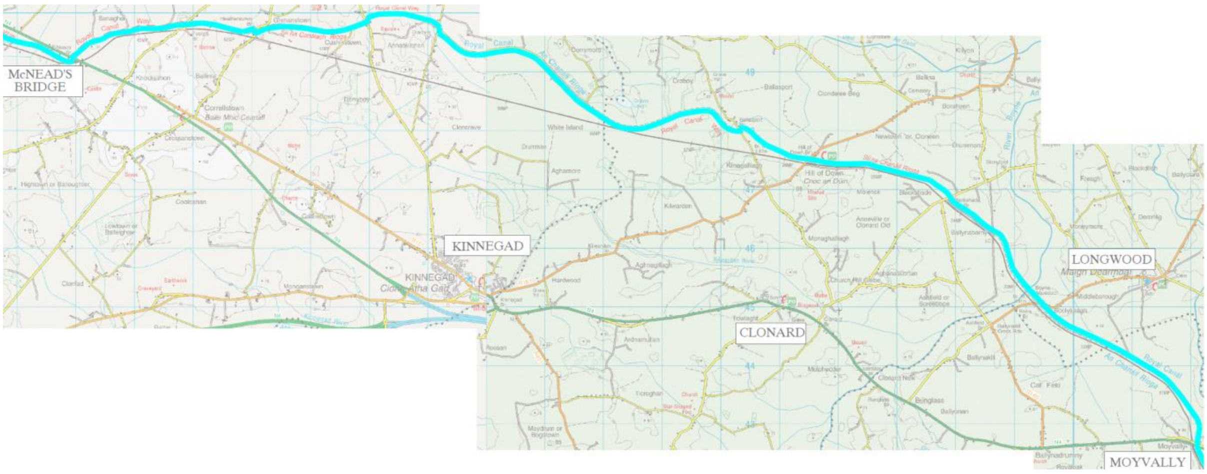

Figure 6: Preferred Route for Section 2 along the Royal Canal Towpath

Section 3: Royal Canal Towpath. Route can be seen in blue below in Figure 7.

Figure 7: Preferred Route for Section 3 along the Royal Canal Towpath

Section 4: Royal Canal Towpath. Route can be seen below in blue in Figure 8.

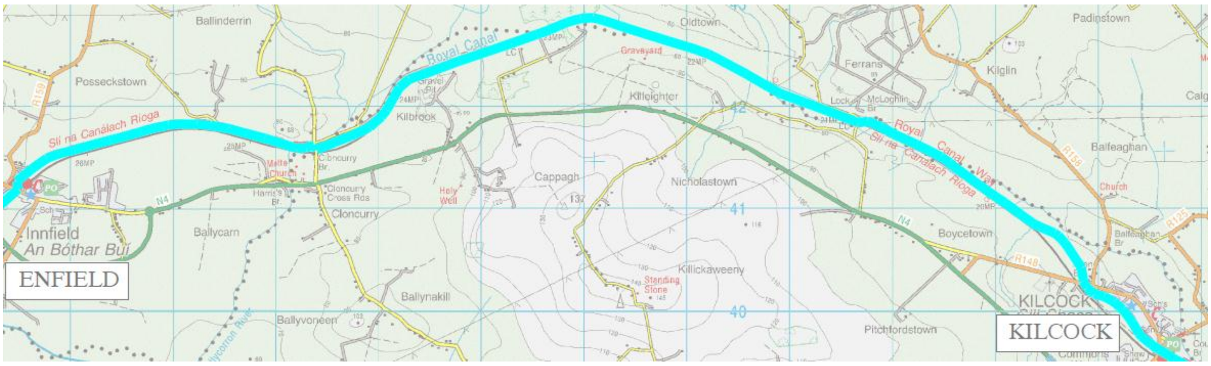

Figure 8: Preferred Route for Section 4 along the Royal Canal Towpath

For Section 5: Royal Canal Towpath. Route can be seen below in blue in Figure 9.

Figure 9: Preferred Route for Section 5 along the Royal Canal Towpath

Section 6: Hybrid of Royal Canal Towpath and R148. Route can be seen in blue below in Figure 10.

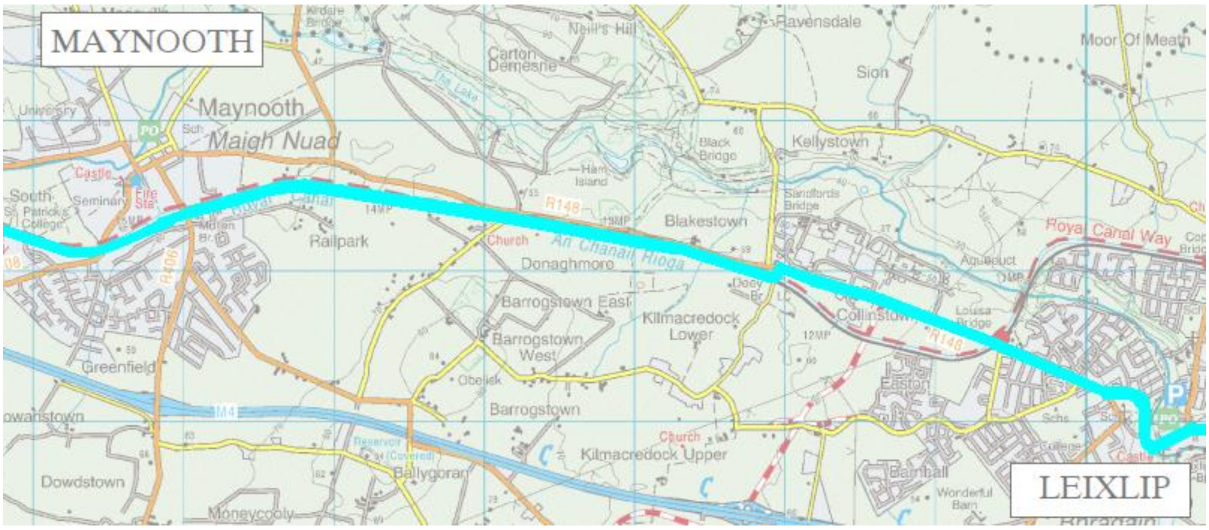

Figure 10: Preferred Route for Section 6 along the Royal Canal Towpath and the R148

Section 7: R148/N4 route or alternative route through Lucan Demesne. Routes can be seen below in blue (R148/N4) and red (Lucan Demesne) in Figure 11.

Figure 11: Preferred Route for Section 7 along the R148 with Alternative Route through St Catherine's Park and Lucan Demesne

This preferred route is based on linking the cycleway into an existing network (Leixlip) which has the Intel complex adjacent to it. However, for the Leixlip to Lucan section of the route, neither the road nor the canal presented an ‘ideal’ solution as both options require cyclists to come into close contact with vehicles in order to get into Lucan village. The road route would have less negative attributes if the route deviated through St. Catherine’s Park and Lucan Demesne. This would allow for the road route to improve in terms of safety, attractiveness and comfort whilst maintaining directness. However, this route requires further investigation into the possibility of passing through parks. Future surveys could establish which of the routes would incorporate fewer deterrents for its use.

3. Conclusions

The overall preferred route allows for a direct and safe route to be created between Dublin and Mullingar. The route allows for a comfortable path to be constructed whilst utilising the existing infrastructure available. A coherent and reasonably continuous path can be formed along the preferred route. The scenic surroundings of the Royal Canal, along with many tourist facilities adjacent to the route will also function as an attraction for potential cycling tourists. The chosen preferred route aims to satisfy the criteria outlined in the route selection report for the requirements of cyclists.

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Appendix 2: Tourist Survey

<u>Tourist Survey on Cycling in Ireland</u>

This survey was created by the Department of Civil, Structural and Environmental Engineering in Trinity College Dublin. In order to design and engineer cycling facilities that cater for tourists, it is important that attitudes, perceptions and opinions of tourists on cycling be fully understood. This survey will determine the qualities that people visiting Ireland and other countries value most when it comes to cycling and will allow cycling facilities to be planned more effectively. The survey is split into three sections.

Section 1 – General Questions   Section 2 – Scenarios   Section 3 – Personal Details

<u>Section 1 – General Questions</u>

What was your main reason for this visit?

Business ☐ Holiday/Recreation ☐ Visiting friends/relatives ☐ Mix ☐ Other ☐

How long do you plan on staying in Ireland in total? ______

Have you cycled, or do you plan on cycling in Ireland while visiting? Yes ☐ No ☐

If yes, how many days do you plan on cycling/have you cycled? ______

And, how did you source the bicycle?

Rented bicycle ☐ Brought own bicycle ☐

Borrowed bicycle ☐ Other (please state) ☐

____

Have you previously visited Ireland? Yes ☐ No ☐

Would you visit Ireland again? Yes ☐ No ☐

Would you recommend visiting Ireland from your experience of cycling? Yes ☐ No ☐

How would you rate the cycling facilities in Ireland (✓ one box only)?

Excellent ☐ Satisfactory ☐ Inadequate ☐ Very Inadequate ☐ Other (please state) ☐

____

Would improvements to cycling facilities encourage you to visit again? Yes ☐ No ☐

How would you characterise your cycling experience (either directly from you cycling or from what you have seen) from the perspective of safety from traffic collisions (✓ one box only):

Very Safe ☐ Safe ☐ Dangerous ☐ Very Dangerous ☐ Other (please state)☐ ______________

If where you are staying there was a high quality Greenway/path that had access to various tourist attractions, would you use the facility? Yes ☐ No ☐

Would the distance of a hotel to a high quality Greenway/cycle path encourage you to stay in a hotel that is close to a facility over one that is not? Yes ☐ No ☐

If yes, how far from the facility can the hotel be that you would consider using the facility?

Hotel should have direct access to the facility ☐

Hotel should be no further than 1km/0.6 miles from the facility ☐

Hotel should be no further than 3km/1.9 miles from the facility ☐

Hotel should be no further than 5km/3.1 miles from the facility ☐

Hotel should be no further than 10km/6.2 miles from the facility ☐

Section 2 – Scenarios

In this section of the survey you will be asked to imagine yourself in a situation where you are sightseeing by bicycle in rural Ireland and you are travelling between two locations. You will be asked to choose between three options with a specified list of conditions. The options are as follows:

Option A – a road with no cycling facilities – Shared space with vehicular traffic

Option B – a road with cycle lanes – Lane separate to traffic with some vehicular interaction

Option C – a fully segregated cycling facility – Facility with little/no interaction with vehicular traffic

Please read the conditions in each option **carefully** and indicate which option you would choose by ticking the empty box below the conditions in the options.

Scenario 1 (✓ one box only)

Option A – Road with no cycling facilities	**Option B** – Road with cycle lanes	**Option C** – Fully segregated facility
		
The time on this facility is **10** minutes	The time on this facility is **40** minutes	The time on this facility is **10** minutes
The weather is **windy**	The weather is **dry**	The weather is **dry**
The gradients along this facility are **moderate**	The gradients along this facility are **flat**	The gradients along this facility are **flat**

Scenario 2 (✓ one box only)

Option A – Road with no cycling facilities	**Option B** – Road with cycle lanes	**Option C** – Fully segregated facility
		
The time on this facility is **10** minutes	The time on this facility is **10** minutes	The time on this facility is **10** minutes
The weather is **windy**	The weather is **wet + windy**	The weather is **dry**
The gradients along this facility are **flat**	The gradients along this facility are **steep**	The gradients along this facility are **steep**

Scenario 3 (✓ one box only)

Option A – Road with no cycling facilities	**Option B** – Road with cycle lanes	**Option C** – Fully segregated facility
		
The time on this facility is **20** minutes	The time on this facility is **20** minutes	The time on this facility is **40** minutes
The weather is **dry**	The weather is **wet + windy**	The weather is **dry**
The gradients along this facility are **moderate**	The gradients along this facility are **flat**	The gradients along this facility are **flat**

Scenario 4 (✓ one box only)

Option A – Road with no cycling facilities	**Option B** – Road with cycle lanes	**Option C** – Fully segregated facility
		
The time on this facility is **10** minutes	The time on this facility is **20** minutes	The time on this facility is **10** minutes
The weather is **dry**	The weather is **dry**	The weather is **wet + windy**
The gradients along this facility are **flat**	The gradients along this facility are **flat**	The gradients along this facility are **moderate**

Section 3 – Personal Details

Gender: Male ☐ Female ☐

Age: 18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55-64 ☐ 65+ ☐

What is your area of residence?

Great Britain ☐ Other Europe ☐ USA and Canada ☐ Other areas ☐

What is your current marital/relationship status?

Married ☐ Single ☐ In a relationship ☐ Other ☐

In your country of residence, do you cycle for:

(A) Accessing your place of work/education: Yes ☐ No ☐
(B) Recreational/Leisure/Sporting/Social purposes: Yes ☐ No ☐

How long have you been cycling for these purposes? ____

What best describes your current work status? ✓ one box only.

Farming, fishing and forestry work	☐	Professional, technical and health workers	☐
Manufacturing	☐	Services based	☐
Building and construction	☐	Homemaker	☐
Clerical, managing or government	☐	Student	☐
Communications or transport	☐	Education	☐
Sales and commerce	☐	Other (Please state)	☐
Unemployed	☐	________________________________	

What is your highest level of education obtained?

High school or Lower ☐ Diploma ☐
Bachelor Degree ☐ Graduate Degree or Higher ☐

What is your annual household income before taxes (please state the currency)? ____

Do you have a driver license? Yes ☐ No ☐

How many bicycles does your household own or available for use?

None ☐ One ☐ Two ☐ Three or more ☐

How would you rate your confidence as a cyclist?

Very Confident ☐ Confident ☐ Reasonable ☐ Nervous ☐ Very nervous ☐

No Opinion ☐

What type of accommodation are you staying in while in Ireland?

Hotel	☐	Guesthouse/B&B	☐	Rented house/apartment	☐
Own holiday home	☐	Caravan/Camping	☐	Hostel	☐
Friends/Relations	☐	Other	☐		

How much will you spend in the following areas (Approximately)?

Food:	____	Bed and Board:	____
Shopping:	____	Internal transport:	____
Sightseeing/Entertainment:	____`	Miscellaneous:	____

If you have any comments on the survey or on cycling in Ireland, please include these below:

____

____

____

____

Appendix 3: Study Area Survey

Commuter/Recreational Survey on Cycling in Ireland

This survey was created by the Department of Civil, Structural and Environmental Engineering in Trinity College Dublin. In order to design and engineer cycling facilities that cater for commuters/recreational users, it is important that attitudes, perceptions and opinions of the general public on cycling be fully understood. This survey will determine the qualities that commuters and leisure users in Ireland value most when it comes to cycling and will allow cycling facilities to be planned more effectively. The survey should take no longer than 10 minutes to complete.

All those who complete the survey have the option at the end of the survey of entering a draw for a 100 euro one for all voucher

If you have any queries on the survey, please send them to deenihg@tcd.ie

<u>Section 1a – General Questions</u>

Do you presently cycle to and from work/your place of education? Yes ☐ No ☐

If you don't cycle, what mode of transport do you use to get to your place of work/education?

Motor Vehicle (Driver) ☐ Motor Vehicle (Passenger) ☐ Train ☐ Luas ☐

Walk ☐ Bus ☐ Other (Please state) ☐ ______________________

If you cycle to work/place of education - what are the main factors that encourage you to do so?

Please rank the reasons in order of importance with 1 being the most important and 5 being the least important of the selected reasons.

Cheap ☐ Faster than other modes ☐ Help environment ☐

Enjoyable ☐ Convenient to park ☐ Not restricted to timetable ☐

No alternative ☐ Easier/safer to cycle now ☐ Like to be individualistic ☐

Good for health ☐ Other(Please state)______________________________________

If you <u>DO NOT</u> cycle to work/place of education - what are the main factors that encourage you to do so? Please rank the reasons in order of importance with 1 being the most important and 5 being the least important of the selected reasons.

Lack of infrastructure facilities ☐ Lack of facilities at work ☐ Fear of cycling theft ☐

Too hilly ☐ Risk of accident ☐ Windy Weather ☐

Rainy Weather ☐ Wrong Image ☐ Unfit ☐

Too much to carry ☐ Children to School ☐ Lack of time ☐

Habit of using car/bus ☐ Nobody else does it ☐ Need car for work ☐

Other (Please state) ____

What is your travel distance to work/you place of education?

Less than 3km ☐ Between 3 & 5km ☐ Between 5 & 10km ☐

Between 10 & 20km ☐ Over 20km ☐ Work from home ☐

What is your travel time to work/your place of education?

Less than 5 minutes ☐ Between 5 &10 mins ☐ Between10 & 20 mins ☐ Over 20 minutes ☐

How would you rate your confidence as a cyclist?

Very Confident ☐ Confident ☐ Reasonable ☐ Nervous ☐ Very nervous ☐ No Opinion ☐

Do you presently cycle for other purposes (recreation/ shopping)? Yes ☐ No ☐

If you cycle for other purposes - what are the main factors that encourage you to do so. Please rank the reasons in order of importance with 1 being the most important and 5 being the least important of the selected reasons.

Cheap ☐ Faster than other modes ☐ Easier/safer to cycle now ☐

Enjoyable ☐ Convenient to park ☐ Not restricted to timetable ☐

No alternative ☐ Help environment ☐ Like to be individualistic ☐

Good for health ☐ Other(Please state) ______________________________________

If you DO NOT cycle for other purposes - what are the main factors that encourage you to do so.
Please rank the reasons in order of importance with 1 being the most important and 5 being the least important of the selected reasons.

Lack of infrastructure facilities	☐	Fear of cycling theft	☐	Too hilly	☐
Risk of accident	☐	Windy Weather	☐	Rainy Weather	☐
Wrong Image	☐	Unfit	☐	Lack of time	☐
Habit of using car/bus	☐	Nobody else does it	☐		

How often do you cycle?
Almost every day ☐ 1-2 times a week ☐ 1-2 times a month ☐ Never ☐

When was the last time you cycled?
Within the last week ☐ Within the last month ☐ Within the last year ☐ Never ☐

How would you rate the overall quality of cycle facilities in your area (Bike lanes, bike racks and other related facilities)?
Excellent ☐ Satisfactory ☐ Neutral ☐ Inadequate ☐ Very Inadequate ☐

How would you characterise your experience of cycling in Ireland (either direct or observed) from the perspective of safety from traffic collisions?
Very Safe ☐ Somewhat Safe ☐ Somewhat Dangerous ☐ Very Dangerous ☐

How would you characterise your experience of cycling in Ireland (either directly or observed) from the perspective of safety from crime?
Very Safe ☐ Somewhat Safe ☐ Somewhat Dangerous ☐ Very Dangerous ☐

In the past year, have you used a cycle for any of the following reasons? Please ✓ the boxes that apply to you

Commuting to work/place of education	☐	Running Errands	☐
Exercising (Not including stationary exercise bikes)	☐	Visiting Friends and Family	☐
Other Recreation	☐	Racing/Stunt Riding	☐
Other (Please state)	☐	________________________	

Cyclist: How long have you been commuting by cycle to your place of work/education?

Less than 6 months	☐	6 months to 1 year	☐	More than 1 year	☐
More than 3 years	☐	More than 5 years	☐	More than 10 years	☐

Cyclist: In which periods of the year do you cycle most? Please ✓ the boxes that apply to you
May to Aug ☐ Sept to Nov ☐ Dec to Feb ☐ March to April ☐

What of the following amenities are available at your place of work/education or during your trip to work/your place of education? Please ✓ the boxes that apply to you
Bike racks ☐ Safe storage rooms ☐ Showers ☐ Clothing lockers ☐ Other (Please state) ☐

High Quality Cycling Facility:

If a high quality Greenway/cycle path like the one pictured above was constructed near your home that also allowed you to travel upon to access your place of work/your place of education, would you use this facility:

To access your place of work/your place of education? Yes ☐ No ☐
For recreational/shopping purposes? Yes ☐ No ☐

And how often would you use the facility for commuting?

Almost every day ☐ 1-2 times a week ☐
1-2 times a month ☐ Never ☐

Section 1b – Cyclist/Motorist Questions on Experience

Cyclist: While cycling to your place of work/education/for recreation, have you ever had a crash involving a motorised vehicle or a vehicle parked on the roadway? Yes☐ No☐

Cyclist: If yes, how often has this occurred?
Only Once ☐ Approx once a year ☐ Approx one a month ☐ Approx once week ☐ Daily ☐

Cyclist: While cycling to your place of work/education/for recreation, have you ever had a "Near miss" involving a motorised vehicle or a vehicle parked on the roadway? Yes☐ No☐

Cyclist: If yes, how often has this occurred?
Only Once ☐ Approx once a year ☐ Approx one a month ☐ Approx once week ☐ Daily ☐

Motorist: While driving to your place of work/education/for recreation, have you ever had a crash involving a cyclist on the roadway? Yes☐ No☐

Motorist: If yes, how often has this occurred?
Only Once ☐ Approx once a year ☐ Approx one a month ☐ Approx once week ☐ Daily ☐

Motorist: While driving to your place of work/education/for recreation, have you ever had a "Near miss" involving a cyclist on the roadway? Yes☐ No☐

Motorist: If yes, how often has this occurred?
Only Once ☐ Approx once a year ☐ Approx one a month ☐ Approx once week ☐ Daily ☐

Both Motorist and Cyclist: While driving/cycling to your place of work/education/for recreation have you ever seen a crash between a cyclists and a motor vehicle? Yes☐ No☐

Both Motorist and Cyclist: If yes, how often has this occurred?

Only Once ☐ Approx once a year ☐ Approx one a month ☐ Approx once week ☐ Daily ☐

Cyclist: Please rank the five most important route attributes in choosing your cycle commute route (1 being the most important attribute with 5 being the least important of the top 5):

Good pavement ☐
Avoid gradients ☐
Get a good workout ☐
Adequate lighting ☐
Safe from crime ☐
Travel time (Wanting to get to destination quickly) ☐
Safe from motor vehicles on the roadway ☐
Safe from collision with parked cars ☐
Avoiding stop signs/stop lights ☐
Other (Please state) ___________________________ ☐

Both Motorist and Cyclist: Which of the following cycle facilities exist on your commute route? Please ✓ the boxes that apply to you

Cycle Lane (designated portion of the roadway striped for cycle use) ☐
Unsigned shared roadway (roadway without signage or pavement markings) ☐
Signed shared roadway (shared roadway designated by signing as a preferred route for bikes) ☐
Off-road bikeway (a bikeway physically separated from motorised vehicular traffic) ☐
Combination of cycle lane and unsigned shared roadway ☐
Combination of unsigned shared roadway and signed shared roadway ☐
Greenway (wide path shared with pedestrians and free from motorised traffic) ☐
Other (Please state) ____ ☐

Both Motorist and Cyclist: Please rank the top 5 of following cycle Infrastructure improvements that you think would encourage cycling (1 being the most important and 5 being the least important of the top 5):

Convenient places to shower /change clothes ☐
Trails and pathways separated from the road ☐
Greater enforcement of traffic laws to protect cyclists☐
Dedicated bike lanes to and from urban centres ☐
Prohibiting motorised vehicles in certain areas ☐
Dedicated bike lanes within urban centres ☐
Other (Please state) _____________________________☐
A map showing cycle routes ☐
Better lighting at night ☐
More convenient bike parking☐
Secure/covered bike parking ☐
More police patrols ☐
Educational classes on cycling ☐

<u>Section 2 – Scenarios</u>

In this section of the survey you will be asked to imagine yourself in two situations.
Firstly, you will be asked to imagine you are commuting to work/your place of education by bicycle. You will be asked to choose between three options with a specified list of conditions.
Secondly, you will be asked to imagine you are cycling for recreational purposes (Visiting friends/exercising/shopping). You will be asked to choose between three options with a specified list of conditions.

The options in both situations are as follows:

Option A – a road with no cycling facilities – Shared space with vehicular traffic
Option B – a road with cycle lanes – Lane separate to traffic with some vehicular interaction
Option C – a fully segregated cycling facility – Facility with little/no interaction with vehicular traffic

Please read the conditions in each option **carefully** and indicate which option you would choose by ticking the empty box below the conditions in the options.
Note: The varying time in each option is indicative of the different distances that apply for the options

<u>Situation 1</u> – Imagine you are commuting to work/your place of education by bicycle. Given the conditions that apply to each option, which option would you choose for each scenario

Scenario 1 (✓ one box only)

Option A – Road with no cycling facilities	**Option B –** Road with cycle lanes	**Option C –** Fully segregated facility
		
The time on this facility is **10** minutes	The time on this facility is **40** minutes	The time on this facility is **10** minutes
The weather is **windy**	The weather is **dry**	The weather is **dry**
The gradients along this facility are **moderate**	The gradients along this facility are **flat**	The gradients along this facility are **flat**

Scenario 2 (✓ one box only)

Option A – Road with no cycling facilities	**Option B** – Road with cycle lanes	**Option C** – Fully segregated facility
		
The time on this facility is **10** minutes	The time on this facility is **10** minutes	The time on this facility is **10** minutes
The weather is **windy**	The weather is **wet + windy**	The weather is **dry**
The gradients along this facility are **flat**	The gradients along this facility are **steep**	The gradients along this facility are **steep**

Scenario 3 (✓ one box only)

Option A – Road with no cycling facilities	**Option B** – Road with cycle lanes	**Option C** – Fully segregated facility
		
The time on this facility is **20** minutes	The time on this facility is **20** minutes	The time on this facility is **40** minutes
The weather is **dry**	The weather is **wet + windy**	The weather is **dry**
The gradients along this facility are **moderate**	The gradients along this facility are **flat**	The gradients along this facility are **flat**

Scenario 4 (✓ one box only)

Option A – Road with no cycling facilities	**Option B –** Road with cycle lanes	**Option C –** Fully segregated facility
		
The time on this facility is **10** minutes	The time on this facility is **20** minutes	The time on this facility is **10** minutes
The weather is **dry**	The weather is **dry**	The weather is **wet + windy**
The gradients along this facility are **flat**	The gradients along this facility are **flat**	The gradients along this facility are **moderate**

<u>Situation 2</u> – Imagine you are cycling for recreational purposes (Visiting friends/ exercising/ shopping / etc). Given the conditions that apply to each option, which option would you choose for each scenario

Scenario 1 (✓ one box only)

Option A – Road with no cycling facilities	**Option B –** Road with cycle lanes	**Option C –** Fully segregated facility
		
The time on this facility is **10** minutes	The time on this facility is **40** minutes	The time on this facility is **10** minutes
The weather is **windy**	The weather is **dry**	The weather is **dry**
The gradients along this facility are **moderate**	The gradients along this facility are **flat**	The gradients along this facility are **flat**

Scenario 2 (✓ one box only)

Option A – Road with no cycling facilities	**Option B** – Road with cycle lanes	**Option C** – Fully segregated facility
		
The time on this facility is **10** minutes	The time on this facility is **10** minutes	The time on this facility is **10** minutes
The weather is **windy**	The weather is **wet + windy**	The weather is **dry**
The gradients along this facility are **flat**	The gradients along this facility are **steep**	The gradients along this facility are **steep**

Scenario 3 (✓ one box only)

Option A – Road with no cycling facilities	**Option B** – Road with cycle lanes	**Option C** – Fully segregated facility
		
The time on this facility is **20** minutes	The time on this facility is **20** minutes	The time on this facility is **40** minutes
The weather is **dry**	The weather is **wet + windy**	The weather is **dry**
The gradients along this facility are **moderate**	The gradients along this facility are **flat**	The gradients along this facility are **flat**

Scenario 4 (✓ one box only)

Option A – Road with no cycling facilities	**Option B –** Road with cycle lanes	**Option C –** Fully segregated facility
		
The time on this facility is **10** minutes	The time on this facility is **20** minutes	The time on this facility is **10** minutes
The weather is **dry**	The weather is **dry**	The weather is **wet + windy**
The gradients along this facility are **flat**	The gradients along this facility are **flat**	The gradients along this facility are **moderate**

If all the conditions were the same for each option, which option would you choose? ✓ one box only.

Option A – Road with no cycling facilities ☐
Option B – Road with cycle lanes ☐
Option C – Fully segregated facility ☐

Which condition was the biggest influence for you to choose an option for commuting to and from your place of work/education by bicycle? ✓ one box only.

Time ☐ Weather ☐ Route Slope ☐

Which condition was the biggest influence for you to choose an option for cycling for other purposes? ✓ one box only.

Time ☐ Weather ☐ Route Slope ☐

When choosing the option for a trip to and from your place of work/education by bicycle which of the following factors influenced your facility choice most?

Risk of accident ☐ Windy Weather ☐ Rainy Weather ☐
Scenery ☐ Avoiding Gradients ☐ Avoid pollution from traffic ☐
Lack of time ☐ Personal Fitness ☐ Vehicle parking ☐
Other (Please State) ☐ ________________________

Section 3 – Personal Details

Gender: Male ☐ Female ☐

Age: 18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55-64 ☐ 65+ ☐

Where do you live? ____

Where do you normally work? ____

What is your current marital/relationship status?
Married ☐ Single ☐ In a relationship ☐ Other ☐

How many children/dependents do you have?
0 ☐ 1 ☐ 2 ☐ 3 or more ☐

What best describes your current work status? ✓ one box only.

Farming, fishing and forestry work	☐	Professional, technical and health workers	☐
Manufacturing	☐	Services based	☐
Building and construction	☐	Homemaker	☐
Clerical, managing or government	☐	Student	☐
Communications or transport	☐	Education	☐
Sales and commerce	☐	Other (Please state)	☐
Unemployed	☐	____________________________________	

What is your highest level of education obtained?

High school or Lower	☐	Diploma	☐
Bachelor Degree	☐	Graduate Degree or Higher	☐
Other	☐		

What is you total annual household income? (Before tax and USC)

Less than €9,999	☐	€60,001 - €70,000	☐
€10,000 - €20,000	☐	€70,001 to €90,000	☐
€20,001 - €30,000	☐	€80,001 - €90,000	☐
€30,001 to €40,000	☐	€90,001 - €100,000	☐
€40,001 - €50,000	☐	€100,001- €120,000	☐
€50,001-€60,000	☐	More than €120,001	☐

I do not wish to answer this question ☐

Do you have a driver license? Yes ☐ No ☐

How many bicycles does your household own or available for use?

None ☐ One ☐ Two ☐ Three or more ☐

How many cars or vans are owned by or available for use by one or more members of your household? Include any company car or van available for private use?

None ☐ One ☐ Two ☐ Three or more ☐

If you have any comment on the survey, please include these below:

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