Explanation of factors influencing cyclists' route choice using actual route data from cyclists

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

Cycling as a sustainable means of transport brings a number of benefits, which includes improved health and well-being for individuals, improved air quality and climate change, accessibility and reduced traffic congestion at the national level. However, despite the benefits of cycling and the efforts by the government to promote this mode of transport, many short trips in Britain suitable for cycling are still made by motorised transport modes. People seem reluctant to change their mode of travel behaviour in favour of cycling. Therefore, it is important to understand the nature of complicated behaviour of people and the ones of cyclists at first.

The thesis aimed to understand route choice behaviour for cycling for utility purposes in England. The thesis examined why cyclists use their current routes and how various features influence their choices. The thesis also probed the reasons for the choices and the relationship between the choice and the characteristics of cyclists.

A mixed method approach was applied for the thesis, using questionnaires, actual route data collection for quantitative methods and interviews for qualitative methods. This approach allowed the researcher to examine diverse aspects of the research questions, which individual methods were unlikely to address.

The thesis has identified what route features are important for cyclists, and why these features are considered important. In terms of the issues regarding cycling infrastructures, the preferences of cyclists were found to be linked to the fear to motorised traffic on roads, which is a fundamental issue that may not be revealed through quantitative studies. Another key finding identified was that cyclists choose different routes dependent on the conditions applicable even for same trip purposes. In this respect, it was noted that often their choices are forced by prevailing road instructions such as one-way road, although they may be aware that the alternative road conditions may not be good from a cycling viewpoint. However, it was also found that, where practicable, cyclists are likely to choose a route strategically, in a manner that will minimise the physical efforts required for cycling. Finally, based on the observations of the different geographical and environmental characteristics and atmosphere to cycling in two case study cities, the thesis also discovered the segment of the population who could become the main target for promoting the benefits of cycling.

Table of Contents

List of Tables

List of Figures

Chapter 1 Introduction

1.1 Introduction

This thesis aims to contribute to understanding route choice behaviours of cyclists for utility purposes in England. It examines what factors influence the choices of cyclists for their routes and variations in preference for the route factors while also probing the reasons for the choices cyclists make for the current routes they actually use.

The following chapter provides the reasons for the research and briefly states its aims and objectives. It concludes with a summary of the structures of the thesis.

1.2 Rationale of the Thesis

Sustainability is an on-going issue in various fields across the world. In transport, sustainability means supporting the needs of mobility of people and goods with minimum damages to the environment (Rodrigue, 2013). In terms of individual transport, cycling is highlighted as an alternative mode to private cars in urban mobility. The benefits of cycling are large: they are affordable with much less costs towards building infrastructure than for cars, they have no pollutants, save lands, improve health etc (Buis and Wittink, 2000). The U.K. government has also emphasised the role for cycling in improving air quality, climate change, personal health and well-being through increased physical activities, accessibility and reduced congestions through modal shift (DfT,2008a; DfT and DoH, 2010; DfT, 2010).

The potential of cycling is still high. A large number of trips can be made via this method; for example, in London, 300,000 trips per day are made by cycling (TfL, 2010). However, Transport for London (TfL, 2010) reported that 4.3 million trips per day (23%) in London could be ‘potentially cyclable’ out of 18.5 million trips per day based on the London Travel Demand Survey 2005/06 to 2007/08. According to the National Travel survey (DfT, 2013a), individual persons in Great Britain made 38.2% of trips within 2 miles (3.2km) and 65.8% of trips within 5 miles (8km) during 2012. However, only 1.92% of trips were made by bicycle within 2 miles and 2.1% of trips within 5 miles.

The British government announced a target of cycling usage, from 2% to 8% by 2012, in the first National Cycling Strategy in 1996 (Parkin et al., 2008; Gaffron, 2003) and has invested £150 million since 2005 in promoting cycling (Pooley et al., 2011b). Despite efforts to promote cycling, such as Cycling Cities and Towns programmes and the Sustrans Connect 2 initiatives, (DfT, 2011a; Pooley et al. 2013) cycling is still uncommon in Britain, with an average cycling rate of 1.7% in 2012 (DfT, 2013a). This low rate is in contrast to other European countries; for example, 9% of all trips are made by bicycle in Sweden and Finland, while in Germany it is 10%, in Denmark 18% and in the Netherlands 26% (Pucher and Buehler, 2008).

For most people, using a car is more attractive and convenient than cycling. The current transport network is designed for car use, so promoting cycling requires changes or remedying of the current transport network. It is a question of how to change the current road transport network to a proper or better network for cycling. Planners or policy makers always need to make decisions about measures or improvements for cyclists. This requires one condition, which is that policy makers and planners have knowledge about what cyclists or non-cyclists expect for their routes.

The actual choice of people does not always follow what they indicate in preference. In route choice behaviour in transport people either make plans based what they would like or they set out and then make actions based on the available options (Hopkinson et al., 1989). However, the problem is that plans and actions often do not match each other. The preferred routes by cyclists are fairly different from the actual used routes (Winters and Teshke, 2010), and various factors influence this miss-matching, such as there being no route which cyclists want in the city or that the route cyclists want having another weakness such as longer distance or time. At the individual level for route choice, it is more complicated as the characteristics of cyclists or regions where cyclists live are also important factors.

Several studies have tried to answer what route attributes significantly influence the choices of cyclists. Many of these studies focus on evaluating the values of infrastructures or hierarchy of route attributes (Warman et al., 2000; Stinson and Bhat, 2003; Tilahun et al., 2007; Hunt and Abraham, 2007; Sener et al., 2009). These studies clearly showed the relative value of examined items but have limitations, as the choices or preferences of study participants were made in rather ideal situations.

On the other hand, some studies examined the characteristics of chosen routes and compared them with ideal routes. This approach provided the reality of the routes that cyclists actually use and proved that cyclists do not choose their routes based on somewhat skewed criterion, such as shortest distance or use of a cycling facility (Aultman-Hall et al., 1997; Howard and Burns, 2001; Raford et al., 2007; Dill and Gliebe, 2008). However, this approach does not explain why those routes were chosen by cyclists.

In addition to the relative weakness of the previous studies, they also paid little attention to the variations in route choices in various aspects such as cyclists' characteristics or regional environments. The choice of cyclists depends on various factors such as traffic conditions, physical characteristics of the roadway, distance, trip time allowed, or even the characteristics of cyclists. These various aspects make heterogeneity of behaviours of cyclists. Moreover, the preferences of cyclists for routes are not fixed but change over time. Practitioners practically cannot make plans to meet all the demands from various segments of cyclists; they always need to decide what will be chosen and what will be discarded, so understanding differences about demands for cycling routes by different cyclist groups is an important issue for developing policies and strategies.

Understanding behaviours of people does not always mean what is seen on surface. That means knowing and revealing facts behind the facts that are visible. However, little interest has been paid to studying what will be the real reasons or hidden reasons for the choices of cycling routes or preference for route attributes. Deeper understanding of cyclists' behaviours requires communication with cyclists in different forms rather than just numbers. The qualitative approach allows for understanding meanings of the choices from the cyclists' points of view.

The findings from the previous studies are valuable but are also like fragment pieces. They should be linked and placed at the same canvas and the missing parts should be added to complete a painting. Therefore this thesis is designed to show the big picture for the route choices of cyclists through probing variations in cyclists' attitudes, taking out the opinions in mind and linking general preference with specific and actual choices.

The main contributions of this thesis are in two areas. Firstly, the essay will provide practical guidance about targeting the right people and what should be considered in the development of strategies for improving cycling routes. Secondly, it makes a contribution to methodological challenges in cycling route studies while using various methods to examine the aspects of cycling routes that quantitative methods have heavily dominated.

1.3 Research Aims and Objectives

The goal of this study is to probe variations in the factors which influence the choices of cyclists for routes and the reasons behind these choices. More specifically, the study aims to find variations in preferences via various characteristics of cyclists through a quantitative approach and reveal reasons based on real choices via a qualitative approach in order to better understanding the thoughts in the minds of cyclists.

To address the aims, the objectives of the study are summarised below:

Objective 1*: Investigate the factors which influence the choices of cyclists for routes*

The study needs to identify what route factors more or less influence the choices of cyclists as there are lots of potential factors. However, the priorities of the factors are different from person to person and region to region. The study does not focus on comparing certain types of items such as cycle lanes or segregated cycle paths, but explores a more broad range of factors to provide a more comprehensive understanding about the influence of route attributes.

Objective 2*: Investigate variations in the attitudes towards the factors via the characteristics of cyclists*

The attitudes of cyclists to the route factors are not homogeneous. Several studies found that the characteristics of cyclists influence cycling activities (Dickinson et al., 2003, Dill and Voros, 2007, Bergström and Magnusson, 2003). However, differences in cycling route choices have been less studied. There are also a few studies which develop segments of cyclists and derive unique characteristics in cyclists (Dill and McNeil, 2012; Gatersleben and Haddad, 2010; Damant-Sirois et al., 2014; Kruger et al., 2016); however, none of the studies have been conducted to develop segments of cyclists with route choice context. Segmenting cyclists for a certain purpose, in this case for route choice, will provide benefits in setting up specific targets and developing specific measures. Therefore, understanding differences in influences of the route factors in different types of cyclists will expand the scope of understanding about cyclists and add effectiveness in developing strategies for better cycling networks.

***Objective 3**: Investigating the features of the actual routes that cyclists currently use*

One of common problems in behaviour studies is the uncertainty that people will actually choose what they are said to prefer. If the environment of the real world is the same as the environment of the experiment or the moment of the experiment, they will behave as predicted. However, the real world has too many external factors which may make people change their behaviour. In cycling route studies, the studies based on actual routes are said to have had different findings from the studies based on experiments. The former revealed cyclists do not always stick to cycling facilities as they more use ordinary roads instead. This probably is because the route with the cycling facility may have some weakness such as longer distance. It is valuable to know what the actual routes which cyclists use are like and what features they have. This knowledge is different from the general attitudes of cyclists, as this choice will provide a difference side of route choice behaviours in reality.

***Objective 4**: Investigate the reasons for the choices of cyclists based on actual routes*

The problem of the studies based on actual route data in cycling route studies is that they simply show the numbers such as the percentage of main roads or minor roads and the numbers of signalised junctions on routes. With such information, it is unknown why cyclists use such routes. Knowing why cyclists chose the current route will provide understanding of how each route factor works in the real world. For this objective, investigating the reasons behind the choices of cyclists requires a qualitative approach to hear the opinions in the minds of cyclists without prejudgments.

***Objective 5**: Integrate and interpret the findings*

The study investigates the attitudes of cyclists for cycling routes in a mix of four different ways: general attitudes and variations, actual route based attitudes and the qualitative method. Each piece of the study will have different stories as well as similar stories about route choice behaviours of cyclists, so it is necessary to integrate the findings from each part and interpret them comprehensively in policies for improving cycling environments. Objective 5 is the final step in expanding knowledge about cycling routes and the demands of cyclists while providing guidance for practical aspects as well as academic ones.

1.4 Structure of the Thesis

Chapter 2 presents a review of the literature on route choice studies for cycling. It outlines factors which influence route choices and the methods and variables used for developing segments for cyclists. The chapter also compares two approaches, stated preference and revealed preference, which have been popularly used for cycling route preference studies. It then presents mythological approaches adopted in previous studies.

Chapter 3 presents the methodology adopted for the thesis. It first describes what a mixed methods approach is, followed by the overall design of the thesis. It then describes study areas and samples. In the following sections, key methods used for data collections and analysis are presented, and then the research ethics and limitations of the adopted methods are presented at the end of the chapter.

Chapter 4 presents the findings of the analysis of the questionnaire survey. The characteristics and cycling behaviours of the samples are described, and developments of typologies of cyclists for route choices are presented. It presents the overall results from the questionnaire survey, followed by presenting differences via gender, city, confidence level and criteria based cyclist types in order.

Chapter 5 demonstrates the findings of the GPS route survey. It describes cycling behaviours such as mileages and trip times. It then compares the collected routes by trip purposes.

Chapter 6 presents the findings of the interviews for the reasons of the choices of the routes, which are collected by the GPS route survey. Key findings are presented by key themes.

Finally, Chapter 7 draws comprehensive interpretations linking the findings from the questionnaire, GPS route survey and interviews together. It provides recommendations for cycling policies and strategies, especially for planning routes, and it ends with suggestions for future research.

Chapter 2 Literature Review

2.1 Introduction

The study focuses on cycling routes and the choices of cyclists. The literature review mainly presents previous studies in route choices or preferences regarding key influential factors and the methods used for the studies. However, the chapter also reviews studies for more wider and general factors affecting cycling activities, of which some parts are related to preferences of route features.

It begins with exploring the factors influencing cyclists' preferences and choices for their routes. The factors are grouped depending on their characteristics, and this grouping will be used throughout the thesis. This is then followed in section 2.3 with a discussion of the differences in preferences by the characteristics of cyclists, main in terms of their socio-economic demographic. The section also reviews the development of segmenting cyclists and the methods for that segmenting. Section 2.4 explores the two methods popularly used in cycling route choice studies: stated preference and revealed preferences (actual route based studies). The section presents the strengths and weaknesses of the two methods and a justification for actual route based studies with techniques. Section 2.5 then reviews qualitative methods and discusses the advantages of using quantitative and qualitative methods together in cycling route studies. Finally, this chapter ends with section 2.6, which summarises the findings in literature review and research questions of this study.

2.2 Factors Affecting Cycling Route Choices

Cyclists need to decide which route they will ride on before starting a trip. In most cases, if it is not a first time trip, they will use the route that they have used previously. Each of the routes that cyclists chose will have a specific reason or reasons and probably preferable features, or at least better features than the not-chosen alternatives. Cycling route choice studies investigate what features make cyclists choose a certain route and reject others.

Although route choice studies are not completely separated from cycling mode choice studies, relatively route choice studies for cycling have been conducted less. This would be because increasing cycling uses is a main concern for most of the countries with a low cycling usage rate, and so studies about cycling have focused on explaining why cycling uses are low and how that will be increased.

However, because of the questions of why cycling uses are low and how that will be increased, studies about cycling route choice are important. Studies for cycling routes are not only for non-cyclists but also for existing cyclists, as their goals are to provide a better environment for daily cycling. After people start cycling, they will become existing cyclists and their demands for cycling environment will be different from their expectations before they start cycling. Unrealistic expectations of non-cyclists become realistic after starting cycling and also change as they get used to cycling more and more. Therefore making cycling routes comfortable and safe for existing cyclists is as important as making them attractive to non-cyclists. Because of this reason, cycling route studies need to provide a comprehensive understanding of the complex behaviours of existing cyclists about route choices and then move onto demands of non-cyclists.

There are a large number of attributes of cycling routes which may influence the preferences or choices of cyclists. However, it is not possible to include all of them in a single study, so more relevant features should be identified through previous studies first. In the following section the features which will affect cyclists' choices for their route are reviewed.

It should be noted that some of reviewed studies were studied for mode choice contexts. However, if the topics of them are relevant to route choice, they are also included in the review.

2.2.1 Classifying Factors Affecting Cycling Route Choice

There are many possible features along cycling routes that cyclists need to consider when choosing a route. Individual cyclists' personal preferences, the external environment or even the characteristics of the trip may influence the choices. However, some of features are relevant to cycling route choice while others are not. Therefore this section reviews how previous studies categorised route features and then presents how such factors are re-classified for the thesis.

Among many possible factors, infrastructures and traffic-related characteristics are the major elements which a route consists of. Stinson and Bhat (2003) studied relative values of various infrastructures and other factors for cycling route choices. They divided characteristics of cycling routes into two categories: link level and route level. The link level was defined as a group of the features along a route which vary in each segment, whereas the route level was defined as a group of the features which affect the quality of a route in accumulation over the entire route.

- **Link level factors:** road type, car parking, cycling facility, bridge, hilliness, pavement
- **Route level factors:** travel time, cycling facility continuity, delays, cross-streets

The study classified the factors into physical features and non-physical features while giving a name to each of the groups: link level for physical features and route level for non-physical features. The characteristics of the link level factors were clear, while the factors in the route level could be sub-dividable (it was not necessary for the study though).

Hunt and Abraham (2007) categorised cycling route features into four categories: facility characteristics, non-cycle traffic characteristics, trip characteristics and environmental/situation characteristics. Facility characteristics were the factors of physical environments, such as cycling facility, while non-cycle traffic characteristics were factors related with vehicle traffic and pedestrians. Trip characteristics included trip distance and time, whereas Environmental/situation characteristics were factors about the natural and social environment.

- **Facility characteristics :** cycling facility, road type, on-street parking, pavement, showers etc
- **Non-cycle traffic characteristics :** traffic speed and volume, motor vehicle types, heavy vehicles, driver behaviour and interactions with pedestrians
- **Trip characteristics :** trip distance and time
- **Environmental/Situation characteristics :** weather, snowploughing, land uses, political and public support, education, enforcement etc

Facility characteristics were similar to link level factors in the study of Stinson and Bhat, while environment/situation characteristics, non-cycle traffic characteristics and trip characteristics were newly introduced except for trip time in trip characteristics, which was also used as a route level factor in the study of Stinson and Bhat. The study expanded the boundary of the factors, influencing route choices to non-physical and traffic-related elements.

Sener et al. (2009) categorised cycling route characteristics into five groups, including on-street parking, cycling facility types, roadway physical characteristics, roadway functional characteristics and roadway operational characteristics. On-street parking and cycling facilities are actually a part of road-way physical characteristics, but they separated them as their study was more focused on on-street parking and cycling facilities than the other features. Roadway physical characteristics meant physical features along a route such as gradient, while roadway functional characteristics included traffic speed and volume and roadway operational characteristics included travel time. Therefore, fundamentally there were three categories identified: roadway physical characteristics, roadway functional characteristics and roadway operational characteristics.

- **Roadway physical characteristics:** on-street parking, cycling facility, gradient, crossings, stop signs
- **Roadway functional characteristics:** traffic speed and volume
- **Roadway operational characteristics:** travel time

The categorisation of Sener et al. (2009) was also similar to the classification of Hunt and Abraham (2007). Roadway physical characteristics were equal to facility characteristics, while roadway functional characteristics were equal to non-cycle traffic characteristics. Finally, roadway operational characteristics were equal to trip characteristics.

Heinen et al. (2010) reviewed the literature for commuter cycling and categorised the factors influencing commuting cycling into four groups except for the socio-economic factor. Although the review was not intended to summarise the determinants for cycling route choices, many factors were also relevant to cycling route choice.

The four categories included the built environment, natural environment, psychological factors and others. The built environment included all kinds of human-built infrastructures, such as cycling facilities. The natural environment included hilliness, weather, seasons etc., while psychological factors were closely related to the social atmosphere about cycling and cyclists' personal attitudes to cycling, such as habits. Others included safety, travel time, effort and transport costs.

- **Built environment:** road network layout, distance, cycling facility, showers and bicycle parking at a workplace etc.

- **Natural environment:** hilliness, weather, seasons etc.
- **Psychological factors:** habits, motivation for (not) cycling, attitude of people, social norms
- **Others:** safety, travel time and effort, transport costs

As the study considered factors influencing cycling mode choices, there were many external factors included in the classification. So the categories made in the other reviewed studies were all merged into the built environment. However, certain attributes in the psychological factors, natural factors and others were still relevant to cycling route choices; for example, weather and seasons, safety etc. Therefore it is worth including some of the factors for the thesis to examine the values of them for route choices.

However, there were slight differences with the names of the categories. Physical and traffic related features were popularly studied and widely accepted as a group, and trip characteristics such as trip distance and time, as well as the natural environment, such as weather, were also studied. Safety, personal security etc were not dealt and classified for route choice studies; however, these factors may be relevant to cycling route studies too.

All the studies reviewed above also considered socio-demographic factors including age, gender, income etc. Unlike the other factors, the socio-demographic characteristics are the factors that cyclists cannot choose. However, they influence the preferences for the other features (factors) of a route so the socio-demographic factors were used to identify differences in the tendency of the choices of cyclists by the segments of socio-demographic characteristics (for example male vs female).

Based on the previous studies, potential factors are re-classified into 6 categories: physical environment, traffic environment, cyclist characteristics, natural environment, trip characteristics and cyclist concerns (Table 2-1). Overall the categories can be obvious with what factors belong to which. However, a few of them could be debatable. For example, hilliness (gradient) could belong to either the physical environment or natural environment, but in the thesis hilliness was included in physical environment while the previous studies for route choice put it into physical characteristics (Sener et al., 2009; Stinson and Bhat, 2003).

Each of the six categories has different characteristics. Both physical and traffic environments are the factors that cyclists need to choose by their preference, and they are also changeable by each segment of a route. On the other hand, cyclist characteristics, natural environment, cyclist concerns,

Table 2.1 Classification of Factors Affecting Cycling Route Choice

Physical environment	Traffic environment	Cyclist characteristics	Natural environment	Trip characteristics	Cyclist concerns
Cycling facilities (+Continuity)	Traffic volume	Age	Seasons	Trip distance	Safety
Road type	+Heavy vehicle	Sex	Weather	Trip time	Personal security
On-street parking	Traffic speed	Income	Time of day	Trip purpose	
Pavement	Delays	Cycling experience			
Gradient	Driver attitude	Level of comfort			
Junction (+traffic lights/signs)	Pedestrian	Employment			
		Education level			

and trip characteristics are the factors that cyclists usually cannot choose, but they could influence the choices of the factors in physical and traffic environments. Cyclist characteristics could also influence cyclist concerns and natural environment, although the relationships among the factors have not been studied enough.

2.2.2 Route Choice Criteria: Distance, Time, Safety

There have been a few studies which tried to identify what criteria more or less influence cyclists' choices for routes. Route choice criteria are rather different to preferences for route factors. Cyclists will choose a relatively better route among the available routes based on the priority of route choice criteria which cyclists bear in mind. For example, cyclists usually prefer cycle lanes over the ordinary road, but if they think that reducing trip time is more important than any other criteria, they may not stick to using cycle lanes but will choose the ordinary road if it saves time.

Van Shagen (1990) conducted a comparative study of criteria of cycling route choices in two cities: Groningen in the Netherlands and Växjö in Sweden, with about 1,000 cyclists for each city. The criteria considered in the study included time, distance, pleasantness, attractions, safety, slope, and crowdedness. Regardless of the cities, distance was the most important criteria, especially in Växjö where distance was the dominant criterion chosen by 62% of respondents while the other criteria were all below 10%, with time ranked at 2nd with 9%. In Groningen, choice rates were rather evenly distributed through the criteria. Distance was still at a top of choice rate with 24% and attractions (19%), time (18%), pleasantness (15%) followed, while crowdedness (2%) and safety (1%) were rarely chosen.

In the analysis of trip purposes, in Groningen time was the most important for official and social trips while distance was the most important for shopping and homewards ones. In Växjö distance was the most important motive for all trip purposes. The analysis with the data of Groningen showed that a priority in route choice criteria might be flexible depending on trip characteristics; for example in Groningen it was time for official trips while it was distance for shopping.

Westerdijk (1990) surveyed 60 respondents for each in Sweden and the Netherlands to identify the relative importance of the cycling route choice criteria. The study considered distance, junctions with traffic lights or without traffic lights, pleasantness, attractions, quality of the road surface, traffic safety, and gradient as criteria. The results showed that distance was the most important criterion while pleasantness was the second in the countries.

Interestingly, traffic safety ranked in third place in the overall importance, while that was not considered as an important criterion in the study by Van Shagen (1990). The Swedish respondents also thought that traffic safety was a more important factor than pleasantness while the Dutch thought that pleasantness was more important than traffic safety.

In the study by Westerdijk (1990), time was not included in a list of the criteria. The author knew that time and effort were important factors, but he assumed that they were implicitly presented in distance, a number of junctions and gradient (Westerdijk, 1990; p.7) as time is related to distance and delay times at junctions. His assumption is fundamentally right, but the result showed that the junction-related criteria (junctions with lights or without lights) and gradient were relatively lower in weight than the other criteria. Moreover, in the study by Van Shagen (1990), time was the most important criteria for office and social trips in Groningen. So it is in doubt that time is really a factor that is less important, as it can be removed from a list of the criteria and be measured indirectly. However, relevant studies for this assumption are too few, so it should be further studied that time could be equal to distance and removed from a list of route choice criteria.

Safety was also similar to the issue with time above. In the study by Westerdijk (1990), safety was also considered as an important criterion in Sweden, but a relatively less important criterion in the Netherlands. Safety was not included in the study by Van Shagen (1990). Therefore safety as criteria also requires further study.

Both studies found that distance was the factor that cyclists gave top priority. Each of the studies also showed that safety or time were important factors, (not more than distance but more than the other factors). However, only a few studies have been conducted to examine priorities of the route choice criteria. Furthermore, no such study was conducted for the cities in England. The reviewed studies showed that there were regional variations in the priorities of the criteria as well as variations by trip purposes. Therefore it would be worthwhile carrying out a study including distance, time and safety together for the cases with the cities in England.

2.2.3 Physical Environment

As a transport mode, cycling also use the existing road network, so road types are major components in the physical environment for cycling. Cycling facilities are another major part of the physical environment as they improve the conditions for cycling. As a part of the road network of a city, car parking, pavement, intersection etc are also important components. Therefore, the physical environment for cycling means all kinds of physical features in the existing road network and extra physical features to improve conditions for cycling.

The physical environment for cycling has been an important issue for practitioners, researchers, and policy makers as it requires investment with finance. It should be justified what facility is more effective than another before investing money in it, so since the mid-1990's, the interests of the studies for cycling routes have moved into measuring preferences on specific facilities or road types. Many studies have been conducted to measure relative values of cycling facilities and road types or together in mixed conditions. On the other side, pavement quality, car parking etc were paid less attention but studied as a part of the study for cycling facilities and road types.

Cycle lanes, segregated cycle paths, and off-road paths

Overall, three cycling facility types: off-road paths, segregated cycle paths and cycle lanes, were popularly taken into account for route choice studies. Off-road paths are paths usually placed in parks, completely away from traffic and are often shared with pedestrians. Segregated cycle paths are cycle lanes usually placed in the kerbside of roads and separated from traffic by physical barriers. Cycle lanes (often bike lanes) are lanes on roads and usually separated by a marked line and sometimes shared with traffic depending on the width of a road lane.

The findings about preference in cycling facilities are rather inconsistent from study to study, but they can be narrowed into three conclusions.

In general, it has been popularly found that cyclists prefer segregated cycle paths than cycle lanes or off-road paths (Hunt and Abraham, 2007; Hopkinson and Wardman, 1996; Wardman et al., 2000*)*. This is because of the benefits of segregated cycle paths that are away from conflicts or interactions with traffic or pedestrians and are as direct as the road network. Hunt and Abraham (2007) found that cycling on a segregated cycle path was 1.4 times more desirable than cycling on an off-road path with pedestrians.

This finding is also supported by the studies for cycling mode choices (Abraham et al., 2002; Taylor and Mahmassani, 1996; Wardman et al. 1997).

Cycle lanes **Segregated cycle paths**

Off-road paths

Figure 2.1 Examples of the Cycling Facilities

On the other hand, a few studies concluded that cyclists had more positive attitudes to cycle lanes than segregated cycle paths (Stinson and Bhat, 2003; Stinson and Bhat, 2005). This conclusion could be related to the proportion of samples of the studies in which 91% of respondents had an experience in commuting cycling and 78% of them were male.

Another interesting finding was the study of Sener et al. (2009), which showed that cyclists actually, but marginally, preferred using cycling on ordinary roads than cycling lanes. This was not too extraordinary as the study of Taylor and Mahmassani (1996) also found that the preferences between cycle lanes and kerb lanes were not statistically different.

Sener et al. (2009) explained that cyclists actually did not want to be stuck to the inside of a lane, but that they rather wanted to get a psychological freedom and more space for manoeuvring. This explanation could be right, but the sample proportion could be more influential as they collected many participants from cycling clubs, of which many members were usually highly experienced and skilful in cycling with traffic. Moreover, the presented road lane in the two studies was a wider kerb side lane, so the wider section of the kerb lane could act like a cycle lane. Although it could not be marked, respondents could not find any significant difference between cycle lanes and wider vehicle lanes in practice.

In terms of off-road paths, a few studies found that cyclists prefer than cycle lanes (Tilahun et al., 2007*)* or than segregated cycle paths (Winters and Teschke, 2010). The study of Winters and Teschke (2010) found that regardless of conditions such as shared, only for bicycles or unpaved, cyclists indicated that they would choose off-road paths.

However, the results from the study of Tilahun et al. (2007) revealed rather different findings between an analysis of willingness to spend additional times for using an off-road path and the analysis of time value of a facility using a mixed logit model. Unlike the additional time analysis, the logit model estimates indicated that improvement of cycle lanes (16.41 minutes) was more valued than removal of car parking (9.27 minutes) and improvement in off-roads (5.13 minutes). Even removal of parking was more valued than improvement of route conditions by off-roads. However, the study treated off-roads like bike lanes, so the difference between bike lanes and off-roads was only that the latter were off from roads. As a consequence, the relative value of bike lanes could be overestimated and the value of off-roads could be underestimated.

These differences might be caused by various reasons, but especially because of various sample compositions. Many of the studies used mixed samples of current cyclists and potential cyclists or non-cyclists. Using the mixed samples for mode choice will not cause any problems because knowing why people do not cycle is a main aim for those studies. However, for route choice, potential or non-cyclists might not be able to have clear ideas about the actual conditions of cycling routes. Although many people cycle for leisure, the expected conditions in that situation are rather different from the conditions of cycling for commuting (Heesch et al., 2012; Poulos et al., 2015). Therefore the inconsistence with the samples through the studies might have caused the inconsistency of the preferences for cycling facility types, and probably even for the other factors as well.

Road classes

In terms of road types, arterial roads and residential roads are common types, but arterial roads can be sub-divided into major arterial and minor arterial roads depending on a number of lanes. They are also called “major roads". Residential roads are often called "collector roads". Therefore road classes can be sub-divided depending on a researcher's intention.

Preference of road types seems to be consistent, as cyclists preferred residential roads over major roads (Stinson and Bhat, 2003; Winters and Teschke, 2010) and two vehicle lane roads over four vehicle lane roads (Petritsch et al., 2006). However, the preferences on road types were not always fixed, but rather changed depending on additional conditions such as a presence of parked cars, shoulder, bike symbols and bike lanes. Moreover, a certain group of cyclists more preferred major roads with a cycle symbol or cycle lane over ordinary residential roads (Winters and Teschke, 2010). This is important because, firstly, the attitudes to cycling environments are different by types of cyclists and, secondly, the improvement of facilities for cycling would be more important in terms of the recognition of cyclists. The influences by types of cyclists to preferences on the route features are discussed in section 2.3.

Parked vehicles and continuity of cycling facility

Parked vehicles and continuity of cycling paths are also important matters for cycling route choice because they influence the quality of cycling facilities or road types. However, they are usually measured as a part of the measurement of values of these things. Despite that, cyclists indicated that a well-connected cycling facility can give positive effects to cyclists' considerations (Stinson and Bhat, 2003), especially for long distance commuters (Sener et al., 2009).

In terms of a presence of car parking, cyclists preferred cycle lanes without car parking (Stinson and Bhat, 2003; Stinson and Bhat, 2005; Tilahun et al. 2007). Parked vehicles on cycling lanes act like the facility is disconnected, so they reduce the quality of cycle lanes and cycling routes. Another matter with parked vehicles is that vehicles parked on streets cause safety problems for cyclists. Cyclists need to move in and out on a road to avoid parked vehicles, and this behaviour increases the possibility of crashing with approaching cars. An increase in perceived risk of cyclists by parked vehicles is not only an issue in major roads, but also in residential roads (Parkin et al., 2007).

Hilliness

Not all cyclists disliked using a hilly route. Moderate gradient routes were more preferred than flat routes by commuting cyclists, male cyclists (Sener et al., 2009) and experienced cyclists (Stinson and Bhat, 2005). However, hilly routes were a barrier for female cyclists and non-commuters (Sener et al., 2009). Many studies for mode choice also found that gradient was a barrier to cycling (Parkin et al., 2008; Rietveld and Daniel, 2004; Rodriguez and Joo, 2004; Timperio et al., 2006).

It is rather obvious that hilly routes require more efforts to go up and that females would have difficulty in using them, whereas a certain type of cyclist seems to enjoy a challenge for fitness or health (Hopkinson and Wardman, 1996; Pooley et al, 2011b). So, the preference for hilliness also depends on various factors such as characteristics of cyclists and trip purposes. Another point with influence of the gradient of a route will be that although hilliness will be an avoidable feature, as cyclists keep cycling and their fitness increases, they can enjoy moderate hilly routes and become less sensitive.

Other features

There have been studies which examine effects of the other features of the physical environment on the choice of cyclists for routes, including surface quality (Bovy and Bradley, 1985; Stinson and Bhat, 2003; Wardman et al., 2000), bus lanes (Hopkinson and Wardman, 1996), intersections and traffic lights/signs (Sener et al., 2009; Stinson and Bhat, 2003). These factors, including hilliness, did not have a significant influence on cyclists' choices, but influenced relative quality of the route. That means that if the quality is worse, it will be problematic and will be avoided, but if the quality is moderate or good, it will be just fine.

2.2.4 Traffic Environment

There are various traffic-related factors such as traffic volume and speed, heavy vehicles, delays at a junction, driver's attitude and interaction with pedestrians, though these factors have rarely been studied.

Traffic volume and speed

Bovy and Bradely (1985) examined preferences about traffic volume and found that heavy traffic volume was less important than longer travel time, whereas Sener et al. (2009) found that moderate traffic volume and speed were rather acceptable, but that heavy traffic volume and speed were a very important matter for cyclists and that these tendencies increased with male cyclists, commuter cyclists and long distance cyclists. It is interesting that female cyclists were less sensitive to traffic speed and volume than male cyclists. This result could be because of a low proportion of female commuter cyclists in the study: 29% of the samples were female and 45% of them were a commuter cyclist, while only 13% of the whole samples were female commuter cyclists.

Traffic speed has been studied in relation with safety matters. Petritsch et al. (2006) found that traffic speeds over 40mph (64km/h) increased crash rates on a cycle lane. Winters et al. (2011) also found that car, bus & truck traffic on the road and vehicles with a high speed over 50km/h were major barriers to cycling. However, as it might be able to be noticed, all the studies mentioned were about mode choices and not route choices.

Others in traffic environment

In terms of heavy vehicles, delays at a junction, driver's attitude and pedestrians, very few studies have been conducted. A stop sign and traffic light at a junction caused delays, so cyclists tended to avoid junctions (Sener et al., 2009; Stinson and Bhat, 2003). Furthermore, experienced cyclists were more sensitive to a number of stop signs and traffic lights than inexperienced cyclists (Sener et al., 2009; Stinson and Bhat, 2005). This tendency may be because experienced cyclists might not want to reduce their cycling speed due to a traffic light or stop sign. On the other hand, none of the previous studies dealt with heavy vehicles, drivers' attitudes and pedestrians in route choice contexts.

Despite the importance of the interactions between vehicles (or pedestrian) and cyclists, not many studies have been carried out about that topic. Many studies presented in this section concluded that traffic related factors are important due to safety. The conclusion will be right, but it was still just an assumption, so there should be further research into whether traffic related factors are really connected with safety issues or anything else.

2.2.5 Cyclist Characteristics

Cyclists' personal characteristics have an impact on the preferences or choices for individual features along routes as well as cycling behaviours. Age, gender and income have been popularly included in cycling studies, while education, employment, experience and comfort levels have been less popular. However. experience and comfort level seem more influential than the other characteristics. A key role of these two is to moderate the effect on the choices of the route features, so different preferences for certain variables are found by the characteristics of cyclists.

Experience and comfort level

The discussion goes first with experience and comfort level. Although experience and comfort level are not popular variables in cycling studies, they are potentially important characteristics for route choices because route choice is a matter for not only potential cyclists but also existing ones. A few studies found that there were differences in preferences in cycling routes even for the existing cyclists.

There were differences in experience and comfort level (Hunt and Abraham, 2007) in preference for cycling route features. Increased experience level and comfort level decreased preference in using cycling facilities and causes a dislike towards using roads with vehicles (Hunt and Abraham, 2007; Sener at al. 2009; Stinson and Bhat, 2005). However, a more detailed segmentation into *highly experienced*, *moderately experienced*, *moderately inexperienced* and *highly inexperienced* revealed rather inconsistent results. For example, *moderately inexperienced* cyclists less preferred cycle lanes than *highly inexperienced* cyclists, whereas *highly inexperienced* cyclists less preferred off-road paths than the others. It seems that off-roads may be more convenient for cycling for less experienced cyclists, but off-roads were less preferred by *highly inexperienced* cyclists. If so, there are probably reasons for this result, but they were not explained in the studies.

This inconsistency may be due to segmentation methods of experience levels or comfort levels, of which a more detailed discussion about is presented in section 2.3.

Gender

Female cyclists preferred using off-road paths slightly more than male cyclists regardless of conditions (Garrard et al., 2008; Winters and Teschke, 2010). Furthermore they were willing to spend more time to use a better facility than men (Krizek et al. 2005). However, these findings had a few problems. They were not statistically significant or not tested for statistical significance, and the size of the female samples was too small compared to the male sample size, although it was due to the relatively low cycling rate of women.

Sener et al. (2009) found that male cyclists were more sensitive than females to changes in on-street parking types and traffic volume, while they were less sensitive to hilliness, cross street, stop signs and traffic lights. However, the overall priorities in the preference for the features were not different, just stronger or weaker in the preferences for each other.

More studies have been carried out to identify differences in cycling behaviours through the characteristics of cyclists. Male cyclists cycled more than female ones (Dickinson et al., 2003; Dill and Voros, 2007; Edmond et al., 2009; Krizek et al., 2005; Moudon et al., 2005; Plaut, 2005; Rietveld and Daniel, 2004; Rodriguez and Joo, 2004; Ryley, 2006; Stinson and Bhat, 2005; Tilahun et al., 2007). The reason that women cycle less than men could be that women do more activities with other family members. For instance, Dickinson et al.(2003) found that women tended to use a car to collect or to drop off their children for school or go shopping on the way to or from work more than men. Pooley et al. (2011b) also found that giving a lift to a family member was a barrier to cycling for various reasons, including extra safety concern, complexity of multi-purposes journey and carrying extra things. Using a car provided much more convenience when making a journey with family members.

Ages

The relationship between cycling and age is arguable, and the influence of age was quite dependent on specific locations or countries. Overall elderly people cycled less than younger people (Dill and Voros, 2007; Moudon et al., 2005; Pucher et al.,1999) while some studies found that there were differences but statistically not significant (Kitamura et al., 1997; Wardman et al., 2007; Zacharias, 2005). A Swedish study by Bergström and Magnusson (2003) also found that older people less cycled in winter than younger people, although it is not clear whether elderly people in other countries also cycle less in winter because few studies have been done about the seasonal impact on cycling of elderly people.

The influence of age was different depending on countries. Pucher and Buehler (2008) compared cycling rates of five countries including Denmark, Germany, Netherlands, USA and UK by age. In the UK and USA, cycling rates by ages were not different, and cycling levels in the Netherlands, Denmark and Germany remained high even among the elderly.

Income level

The influence of income level on cycling is also arguable. Pucher and Buehler (2008) concluded that people with higher incomes cycled more than people with low incomes. However, Parkin et al. (2008) found that higher incomes were related with lower cycling to work. On the other side, Xing et al. (2010) found that a higher income level had a greater influence on recreational cycling than commuting cycling, as wealthy people pay attention to their health and can afford cycling for health purposes as well as in terms of money and time. So the difference in income level is still not concretely concluded, but it seems that it is more linked with the purpose of cycling. Therefore more studies are required regarding income levels, and probably trip purposes as well.

The characteristics of cyclists influence cyclists' choices and preferences on individual features, and experience and comfort levels seem more influential than the other characteristics. However, The characteristics of cyclists were not a major factor overall and they rather moderated strength of preference on certain features. However, not many studies actually included these factors in their research on route choices, so more studies are required for probing the relationship between route choice and the characteristics of cyclists.

2.2.6 Natural Environment

Cycling is different from the other transport modes as it is greatly influenced by the natural environment. Cycling is powered by the energy of individuals, and cyclists are fully open to the air. Weather, season and landscape are all possible factors that can influence cyclists' choices.

Season and weather

Few studies have been done on the influence of seasons and weather on route choice, and most studies about the influence of these factors were for mode choice studies. Overall, people cycled more in summer than winter (Bergström and Magnussen, 2003; Guo et al., 2007; Stinson and Bhat, 2004). Furthermore, it was found that cycling distances in winter also significantly decreased (Bergström and Magnussen, 2003), whereas cyclists tended to choose a better cycling facility less in winter (Tilahun et al., 2007).

Daylights

The reason that cyclists chose better facilities less in winter may be related to daylight hours, which are shorter in winter. Cyclists preferred cycling when it became dark (Stinson and Bhat, 2004; Gatersleben and Appleton, 2007) and it was more important for women (Bergström and Magnussen, 2003). Daylight can be a more relevant variable to route choice than seasons or weather, and even more related with commuter cycling trips, especially made after any work time in winter. Cyclists might choose a shorter route in distance or time as they dislike cycling in darkness.

Scenery

Scenery is related with the attractiveness of a route, and it may be quite dependent on trip purposes and seasons as well. In summer, with people having more time after finishing work, cyclists may choose a route with good scenery, while in winter they may not be interested in the scenery along a route.

Overall very few studies have been done for route choice with natural environments. Seasons and weather conditions could probably be less influential on route choice but more influential for whether to cycle or not, whereas daylight and scenery could be an influential factor (although the impact could be quite limited).

2.2.7 Trip Characteristics

Trip distance, time and purposes influence the decisions of cyclists on a route. Trip distance and time have been often studied as criteria of route choice, and the studies revealed that distance was the most important criterion (Van Shagen, 1990; Westerdijk, 1990).

Trip distance

Trip distance is also closely related with the size of a city and partially road network. Southworth (2005) found that denser road networks were more suitable for cycling. Many studies also found that a higher density of residence had higher cycling uses due to shorter trip distances (Guo et al., 2007; Parkin et al., 2008; Pucher and Buehler, 2006; Zahran et al., 2008). On the other hand, Moudon et al. (2005) and Zacharias (2005) argued that there was no clear and significant evidence in the relationship between the density of a road network and the cycling uses. Trip purposes have also probably influenced preferences for distance of cycling routes, especially commuting cycling for which distance was an important factor for route choice (Cervero, 1996; Dickinson et al.2003; Parkin et al., 2008).

Trip time

Increased trip time decreased the attractiveness of cycling as a transport mode (Noland and Kunreuther, 1995; Wardman et al., 2007). Trip time was the most important factor on the route choice for experienced cyclists, but not for inexperienced ones (Stinson and Bhat, 2005). However, trip time was relatively less studied than trip distance.

Trip purposes

A few studies have found that cyclists' choices or preferences differ by trip purposes, especially commuter cycling. Commuter cyclists in Groningen, the Netherlands chose time as the most important criteria, while distance was the most important criteria for shopping and home trips (Van Saggen, 1990). Commuter cyclists were also more sensitive to hilliness and traffic volume (Sener et al., 2009).

Unlike leisure cycling, often even utility cycling, cycling to work in the morning occurs under a few constrains such as a fixed arriving time, heavy traffic in peak time etc. So cyclists change the priority of route choice criteria depending on trip purposes.

Trip characteristics are important because cyclists' choices could be changeable by them. Even though cyclists prefer a certain type of facility or route features, they will consider advantages and disadvantages of using a certain facility under the trip characteristics. If it is a just an out-going trip at weekends, cyclists will use off-road roads in parks for refreshment. On the other hand, if a cyclist needs to cycle for shopping, he/she may use a route that is relatively fast and comfortable with less traffic. Despite the importance of the trip characteristics, they are a very limited amount of studies about how they influence the choices of cyclists.

2.2.8 Cyclist Concerns

Safety and traffic

Safety is an important concern for cyclists, and especially for non-cyclists, acting as a deterrent which makes people not cycle (Pucher et al., 1999; Pucher and Buehler, 2006; Rietveld and Daniel, 2004; Southworth, 2005; Stinson and Bhat, 2004).

People will avoid a place that they feel is dangerous. Cyclists will also avoid routes that have any dangerous elements. Safety concerns include most of the dangerous situations and conditions that cyclists face. Traffic is the commonly identified sources in creating dangerous situations or conditions (Davies et al., 1997; Davies and Hartley, 1999; Henson et al., 1997; Winters et al. 2010), as well as aggressive vehicle driver behaviour (Davies et al., 1999; Henson et al., 1997).

Several studies concluded that cyclists were more sensitive to risk-related variables, though it was mainly traffic (Bovy and Bradley, 1985; Hopkinson and Ward-man, 1996; Winters and Teschke, 2010). A main reason to use a cycling facility is safety, as it might reduce risk of traffic (Sener et al. 2009; Winters and Teschke, 2010), and experience would moderate perceived risk (Hunt and Abraham, 2007; Stinson and Bhat, 2005).

Safety and junctions

Traffic itself is not the only factor influencing the feeling of cyclists. Junctions are also an important factor as it is hardly possible to cycle without crossing junctions, whatever type, where there are conflicts against traffic. Most of cycling accidents actually happened in a junction or nearby (RoSPA, 2013).

Landis et al. (2003) found that traffic volume, the size of a junction (crossing distance), and the width of the kerb-side lane were the key variables for judging a level of service of a junction. Parkin et al. (2007) found that cyclists thought that using a roundabout was more dangerous than using a signalised junction. Parkin et al (2007) also found that right turning was a more dangerous activity than going straight. So safety matters regarding junctions are linked to junction types as well as turning direction.

Personal security

Few studies have been found on the relationship between personal security and cycling route choice. It may be a more relevant factor for mode choice, but it is possible that cyclists may avoid a certain area in case that area is known as hazardous, and particularly when it is dark. So this would be a potential factor to make cyclists take a detour from a usual route.

Safety was an important factor influencing mode choice for cycling, but it is rather unclear for route choices. It is generally true that people do not want to go where they feel it is dangerous, and this statement can be applicable to route choice as well. Cyclists may not choose a route which they feel is dangerous. Several studies found that traffic and traffic-related features are a key source of risk to cyclists (Carter et al., 2007; Landis et al., 2003; Wang and Nihan, 2004). However, it is not clearly known what features of traffic or anything else are related with feeling unsafe and how much. Therefore further studies will be required to find the relationship between safety and various other factors.

2.2.9 Summary of Section 2.2

The factors influencing cycling route choice were categorised based on the previous studies into six groups, including physical environment, traffic environment, cyclist characteristics, natural environment, and cyclist concerns (see Table 2.1 for the detailed factors).

Physical and traffic environment were studied to probe what features of them were more or less important or preferred often with various conditions. Cycling facilities and road types together in particular were popularly examined. On the other hand, trip characteristics and cyclist concerns were used to identify important criteria for route choice, and distance was found as the most important criteria overall.

In terms of the features in cyclist characteristics, they were used to identify different patterns in preferences for other features of the other groups by segments of each characteristics, such as gender, age and experience. The features in a natural environment were rather less relevant to the route choice context, but time of day may affect the choice of cyclists.

Most of the previous studies focused on the physical and traffic environment, especially cycling facilities and road types. Some of the findings from the previous studies for the factors in physical and traffic environment were consistent, while some were inconsistent in preferences. The inconsistency was high, especially in cycling facilities.

The inconsistency in the preferences may be caused by the mixed samples of current cyclists, potential cyclists or non-cyclists. Using the mixed samples for mode choice will not have any problem because knowing why people do not cycle is a main aim for mode choice studies. However, for route choices, potential or none cyclists might not be able to have clear ideas on the actual conditions along cycling routes. Therefore, using the mixed samples would not be appropriated and there may be differences when conducting studies with only current cyclists.

Despite extensive studies for cycling facility and road types, the other factors were relatively less studied, including time, safety, junctions and natural environments. The review also showed that the preferences for cycling routes were quite changeable depending on cyclists' characteristics and different regions. Experience, the comfort levels of cyclists and trip purposes especially will be a significant factor for route choices. Therefore, more studies with these variables are required.

Importance and preference on a certain feature is a quite different context because the one preferred by a cyclist may not be important for a decision. The relative importance of the factors is particularly an important issue as it provides the evidence to make priorities in developing policies and strategies and investment. Fragmental comparisons between a few or several variables are less clear in terms of what is more or less important for route choices, as each study may have a different experimental environment; for example, different samples and different questions for a survey. Therefore it requires making comparisons to the route features under the same conditions through various ways.

2.3 Classifying Cyclists

It is obvious that people do not think or behave in the same way. People change their perception or behaviours as they progress from one stage to another (Davies et al., 2001; Prochaska et al.,1994), and the same thing will happen with cyclists for route choice or preference. Cyclists or non-cyclists on each stage have different attitudes to cycling and different demands to start or keep doing it (Gatersleben and Appleton, 2007). Therefore, knowing differences by the characteristics of cyclists is important in setting up clear targets or goals for making plans for new cycling facilities or routes as well as developing strategies for promoting cycling.

Segments by experience level

Most studies which have tried to identify differences or similarities by the characteristics of cyclists generally used socio-demographic variables such as gender, age, education etc. Making groups using the socio-economic variables was a basic attempt to identify differences in preferences or behaviours of cyclists and showed that the behaviours of cyclists were not homogeneous but heterogeneous (Bergström and Magnusson, 2003; Dickinson et al., 2003; Dill and Voros, 2007). On the other side, there were a few studies which turned their attentions to different characteristics of cyclists rather than the socio-demographic variables to gain a deeper understanding about different behaviours and preferences of cyclists.

Stinson and Bhat (2005) compared route preferences by cyclists' experience levels and interests to commuting by bicycle. The study divided participants into three groups, including *experienced cyclists*, *inexperienced cyclists with an interest in commuting*, and *inexperienced cyclists with no interest in commuting*. The terms of *experienced* and *inexperienced cyclists* were defined with a little modification, based on the classification of the Federal Highway Administration (FHWA), USA. It can be seen that 91.1% of the samples of the study were *experienced cyclists*, while 6.3% of them were *inexperienced but interested*, and 2.6% were *inexperienced and uninterested cyclists*. They found that there were differences between *experienced* and *inexperienced cyclists* in the factors which influenced their route choice. 'Minimizing travel time and delay' was the most significant factor for *experienced cyclists,* while 'Major roads' was the most significant factor for the *inexperienced*.

The study showed there were differences in the significantly influencing factors to route choice by non-demographic characteristics of cyclists. However, there were a few unclear points with the terms of 'experienced and inexperienced'. The study required respondents to justify themselves whether experienced or inexperienced in cycling to work without any standard. So the distinction between experienced or inexperienced in cycling to work was purely dependent on the personal judgement of the individual respondents, and it would not have consistency in measuring the actual experience of the respondents.

Another study (Sener et al., 2009) also used cyclists' experiences as cyclists' characteristics as well as many other characteristics, such as gender, age, reason for cycling etc. However, overall the findings related with cyclist characteristics were rather unclear, although there were a few differences in preferences by experience or gender. For example, cross-streets had a high impact on less experienced cyclists, while high speed limits had a high impact on little experienced cyclists.

In the study, the experience of cyclists was measured more rationally than the study by Stinson and Bhat (2005). The study defined 'experienced' as having cycled more than a year with 65% of the samples for commuting belonging to the experienced group, while 90% of the samples for non-commuting belonged to the experienced group (Torrance et al. 2007[1]). As a consequence, more clear definitions about experienced or inexperienced cyclists are studied.

Segments by comfort level

On the other side, one of key cyclist types was categorised by Geller (2011), the team leader of cycling plans in Portland, USA. He grouped cyclists into four types using comfort levels in different types of cycle ways. This categorisation was initially made based on Geller's professional experience in promoting cycling in Portland and was not validated by any reliable methods. However, the categorisation was popularly referenced by bicycle planners in many other cities or regional bike plans (Dill and McNeil, 2012).

The categorisation by Geller was then validated by Dill and McNeil (2012). Like Gellers' work, they used the comfort level of cyclists on various types of streets and interest in cycling for categorisation. The study measured comfort levels using five types of cycling roadways below:

1. Separated cycling paths,
2. Quiet residential streets with traffic speeds of under 25 miles per hour,
3. Two lane commercial streets with on-street parking, no-cycle lane and traffic speeds of 25-30 miles per hour,
4. Major street with four lanes, on-street parking, no-cycle lane and traffic speeds of 30-35 miles per hour,
5. Major street with four lanes, on-street parking, no-cycle lanes and traffic speeds of 35-40 miles per hour.

Interest in cycling was measured by the response to "I would like to travel by bike more than I do now" and cycling behaviour in the past 30 days. The respondents were then grouped under four different titles: *Strong and Fearless, Enthused and Confident, Interested but Concerned*, and *No way No How*.

They found that the distributions of the adult population in Portland for the four types were very similar to Geller's estimates, and this similarity meant that this kind of typology could be useful for planning purposes, although this categorisation could vary from city to city.

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[1] The study by Sener et al. (2009) and Torrence et al. (2007) share the same samples.

The study categorised cyclists and tried to measure their cycling ability on the roads with more rational methods than the previous studies. However, the study included non-cyclists and the term used in the study was rather different from an ordinary meaning of non-cyclists. Non-cyclists in the study meant the respondents who did not cycle in the last 30 days. Therefore, even the types of *Strong & Fearless* and *Enthused & Confident* had a large portion of non-cyclists in their groups: 34% and 28% respectively. This does not make sense, as even completely non-cyclists might be included in those types. This could be a potential problem in considering cyclists and non-cyclists together for classification process.

The study also revealed that comfort level of cyclists varied by bikeway types. However, traffic related factors will also have significant elements for measuring cyclists' ability on roads. Therefore, the study may leave the potential for studying the comfort level of cyclists with traffic or other factors.

Factor-cluster analysis method

The previous studies shown above used rather immature methods, but there have been the studies which used a quite different approach to categorising cyclists using factor-cluster analysis (Damant-Sirois et al., 2014; Gatersleben and Haddad, 2010; Kruger et al., 2016).

Gatersleben and Haddad (2010) conducted a study to identify stereotypes of cyclists in England by capturing various images of cyclists from not only cyclists themselves but also non-cyclists. The study revealed 4 types of cyclists including *Responsible, Lifestyle, Commute* and *Hippy-go-lucky.* Each type had different images by themselves and from those seen outside. The study found that each type had differences in priority for the matters related to cycling activities; for example one attribute used in the study was 'Cycles as Fast as Possible', and this attribute was a significant characteristic for the cyclists in *Lifestyle* and *Commute* types who spent time and money on cycling and regularly cycled to work respectively.

The study by Damant-Sirois et al. (2014) also used factor-cluster analysis with preferences and deterrents including weather, effort, time efficiency, cycling near cars, infrastructure, encouragement from peers, institution and parents, enjoyment, and cycling identity. The study excluded non-cyclists for samples.

The study derived 4 cyclist types: *Dedicated Cyclists*, *Path-using Cyclists, Fairweather-utilitarians* and *Leisure Cyclists*. For *Dedicated cyclists,* cycling time, and encouragement by peer and institution were the most important factors for cycling activities. They also thought of themselves as cyclists and enjoyed cycling, but less so than *path-using* and *leisure cyclists.* Instead, weather conditions and cycling facilities were not important factors for them. For *path-using cyclists*, cycling facilities were the most influential factor, and most of the factors influenced their cycling activities except for weather & effort and peer & institution encouragement. *Fairweather-utilitarians* were significantly influenced by weather conditions; they did not prefer cycling under bad weather and did not think of themselves as cyclists, and they certainly did not enjoy cycling. *Leisure cyclists* did not care about time for cycling activities as expected, and enjoyment was their most important factor.

Both studies showed a significant advance in methods for classifying cyclists. They used factor analysis and then cluster analysis with attributes about behaviours, motivations, deterrents and even images which measured from questionnaires. This approach allowed categorising a target in multi-dimensions related with cycling and cyclists, not only the behaviours of cyclists but also external factors. This method was highly applicable to other typology studies for cyclists.

Another study using factor-cluster analysis was done by Kruger et al. (2016). They categorised cyclists to know who would actually participate in a cycle tour event using various motivations. They identified three cyclist types: *Regulars*, *Devotees* and *Beginners.* An important thing to note in this study is that categorising cyclists for different purposes might derive different results from previous studies. For example, the motive *of lifestyle* was an important factor which was not found in previous sport event studies, while *health and fitness* was found as an important factor in the previous studies (Brown et al., 2009; Damant-Sirois et al., 2014; LaChausse, 2006) but not in this one. This result might be caused by the study using more numbers of questions to identify motives for participating in cycling events than the other studies (they used 25 motives), and more fundamentally the study aimed for participating in cycling events not cycling activities. As a consequence, categorising cyclists for different purposes will derive different characteristics of cyclists which explain different behaviours in them.

Conclusion

So far several studies for categorising cyclists were reviewed, and a few points can be identified from the review regarding cycling route choices. Although some contexts were related with cycling route choice matters, such as preferences in cycling facilities with road types and traffic speeds, they were very limited as the studies were not fully intended to identify differences in cycling route preference or choices from different cyclist types.

The studies by Stinson and Bhat (2005) and Sener et al. (2009) used experience as a key distinction to make groups. However, the term of experience was not clearly defined. On the other side, the comfort level used by Geller(2011) and Dill and McNeil(2012) was better justified as they measured the level with several questions which were thought to be related with cycling activities and the comfort level performed well to explain the distributions of cyclist types in Portland, USA. So comfort level has a high potential to be tested in the route choice contexts.

In terms of the method of categorisation, the method used by Geller(2011) and Dill and McNeil(2012) were only good for dealing with one or two factors, while the methods using factor-cluster analysis could deal with more various aspects of a given topic at the same time. Furthermore, the method has not been used for the classification of cyclists in terms of route choices, so it will be a good attempt to categorise cyclists with such an approach based on route choice criteria like the motives in the study by Damant-Sirois et al (2014).

2.4 Stated Preference and Revealed Preference

Stated Preference (SP) studies provide general preference of subjects to objects, while studies using actual data (Revealed Preference: RP) provide real choices for cyclists among the available options. The choices of cyclists in SP studies does not mean that cyclists really use the suggested facilities or route features but rather means there is a willingness or possibility of using them. Respondents might choose a different option in the real world from what they chose in a SP survey. So studies using actual data will enhance and cross-validate findings from the studies using the SP method.

2.4.1 SP based Approaches

Since the mid-1980’s, many cycling studies started to consider more detailed features of cycling activity and routes with complex or mixed conditions. The SP method was popularly used for such studies to compare different conditions of cycling routes (Bovy and Bradley, 1985; Hopkin and Wardman, 1996; Hunt and Abraham, 2007; Sener et al., 2009; Stinson and Bhat, 2003; Tilahun et al., 2007; Warman et al., 2000).

Benefits of SP

SP method could estimate a value of non-existing facilities or factors. The method tested possible alternative scenarios against a current or base scenario to estimate values, in whatever units (money or time), of items by the change of attributes in them (Bovy and Bradley, 1985; Hopkinson and Wardman, 1996). SP was a very useful method to estimate potential impacts of a newly proposed measurement or infrastructure and to compare relative benefits of those new infrastructures or measurements against current ones for transport planning (Hopkinson and Wardman, 1996).

Several studies examined the relative values or preferences among cycling facilities: comparisons of cycling facilities only (Hopkinson and Wardman, 1996) or comparisons in the mix of cycling facilities and other attributes together (Tilahun et al., 2007). The other factors, such as hilliness, pavement, cycling facility continuity, delays, pedestrian, car parking, cross streets and heavy vehicle volume etc, were also tested using the SP method, but mostly in cases with cycling facilities (Bovy and Bradley, 1985; Hunt and Abraham, 2007; Sener et al., 2009; Stinson and Bhat, 2003; Warman et al., 2000). All the studies compared the relative value of each factor by different conditions or against other factors.

Hopkinson and Wardman (1996) conducted an SP survey with 155 interviewees in Bradford, UK. to evaluate the benefits of different possible cycling facilities for the improvement of cycling environments in the city. They made various scenarios in the mix of cycling facilities and travel time and then measured the values of them in cost. They found that introducing a segregated cycle path was more highly valued than a wider nearside lane, which might be not much different from providing marked cycle lanes. They also examined the effect of the introduction of a bus lane. Bus lanes were less attractive than wider lanes or segregated paths, but in general better than standard lanes. However, one of the findings was a little confusing as bus lanes with shorter travel time were less valued than bus lanes with longer travel time. They explained that this could be because of unrealistic time variations in SP design.

Tilahun et al. (2007) also studied trade-offs between various conditions of cycling facilities and travel time in Minnesota, USA using Adaptive SP (ASP). 161 employees from the University of Minnesota participated in the research. The study added an additional feature of on-street parking into scenarios, so the study examined not only values of cycling facilities but also valued the presence of on-street parking. The findings were clear as people had a willingness to spend more travel time using better facilities or route conditions, such as segregated bicycle paths, bicycle lanes and no on-street parking. However, the comparison between bike lanes with on-street parking and no bike lane with no-parking was not tested without any explanation.

Another benefit using of SP is that it allows a large number of samples with a low cost (Hunt and Abraham, 2007), especially with a web-based survey (Stinson and Bhat, 2003; Sener et al., 2009). Hunt and Abraham (2007) conducted a SP study to investigate influences of various factors on cycling behaviour in Edmonton, Canada. They had a total of 1,188 completed questionnaires from the 3,540 they distributed. Stinson and Bhat (2003) undertook a SP study for cycling route choice for link level factors and route level factors. The study recruited 3,145 responses of commuter cyclists over the USA using a web-based survey. Sener et al. (2009) also conducted a web-based SP survey and recruited 1,621 respondents in Texas, USA. Using a web-based survey did not guarantee that the sample would represent the actual population (TCRP, 2006); however, using a web-based survey with other survey methods together would increase the number of samples and representativeness with a relatively low cost and effort.

Researchers can control all the variables in studies using SP, or in other words they can add or remove certain variables via their own intentions. Because of this an SP method provides a great advantage in examining preferences about non-existing variables (factors which are considered for a study), and then make it possible to test potential policies for both mode choice and route choice in transport.

Disadvantages of SP

The weakest point with the SP method is that individual’s choices may not correspond to their actual choices for various reasons (Bonsall, 1983). Although when SP is carefully designed to reflect the real environment, there is little difference between the choices measured in SP and observed in RP (Wardman, 1988), as shown in the study by Hopkinson and Wardman (1996), it is always possible to make unrealistic conditions or scenarios.

It is also possible that respondents could answer in a strategic way. As many respondents in cycling route studies are experienced cyclists in general, they know the issues in the policy on cycling and route planning, so they could answer what they believe that it should be (Bonsall, 1983). Therefore the findings from SP studies should be validated with observed choices to have credibility.

2.4.2 RP based Approach: Use of GIS and GPS

A few studies have been conducted for cycling route choices with actual route data. The studies could be divided by how they obtained actual route data. Some of them collected the data by drawing routes on a map or description by participants (Aultman-Hall et al., 1997; Howard and Burns, 2001; Raford et al., 2007), while the others used GPS to obtain data (Dill and Gliebe, 2008; Menghini et al., 2010). This section presents a brief overview of the studies that used actual route data and then moves to methods and findings.

Overview of the studies based on actual routes

The study by Aultman-Hall et al. (1997) used GIS for analysis of data, but route data was collected by drawings on a map by participants of 338 in Guelph, Canada. The study focused on cycling to work or school. Route characteristics used in the analysis included road types, speed limit, traffic volume, gradient, bridge type, the number of buses and railway crossings. They compared the actual routes with the shortest paths generated by a GIS programme.

Howard and Burns (2001) distributed questionnaires to experienced commuter cyclists in Phoenix, USA to collect cycling route data using a drawing on a map and asked a stress level for the route ranging between 1 and 5 as well as demographic data. They constructed the actual routes in a GIS programme and generated three alternative routes (the shortest route, the fastest route and the safest route) before comparing the actual routes against the alternative ones.

Raford et al. (2007) collected 46 pieces of actual route data from 46 commuter cyclists in London, UK. The data was also collected by the drawing of a route to/from work by participants on a map. The shortest routes and cognitive fastest routes were generated for comparison with the actual routes. The study was initially purposed to prove the usefulness of Space Syntax, so the shortest route was generated by a GIS programme, but the fastest cognitive route was generated by the techniques of Space Syntax.

Dill and Gliebe (2008) collected actual routes travelled by cyclists using GPS equipped PDA and then compared them with the shortest routes generated by a GIS programme. In Portland, USA 536 citizens participated in a questionnaire survey, and 162 cyclists out of them with 1,953 routes were involved in GPS experiments. The study also asked participants to indicate the importance of each of the seven route choice criteria, including ‘Minimizing distance’, ‘Ride in bike lane’, ‘Ride on path/trail’, ‘Ride on signed bike route’, ‘Avoid streets with lots of traffic’, ‘Avoid hills’, and ‘Reduce wait time at signs/lights’. Therefore the study tried to find attitudes of cyclists as well as physical information on the chosen cycling routes. However, the analysis of the study was rather descriptive with the attitudes towards the criteria and simply showed the differences between the actual routes and the alternatives.

Menghini et al. (2010) studied route choice preference with 3,387 stages of cycling collected via GPS in Zurich, Switzerland. They generated the shortest routes and then compared them with the actual routes regarding the variables, including route length, average gradient, maximum gradient, the percentage of marked cycle paths, a number of traffic lights and path size. The study’s purpose was to develop models for cycling route choice, so it did not include many variables which would represent the environments of cycling routes, but rather was limited to a few variables. However, it showed relative influential power of each variable used by the elasticity calculated for the models.

Alternative routes used in the previous studies

As a common method for analysis, all of the studies compared the actual routes with ideal alternative routes, including the shortest route (Altman-Hall et al., 1997; Dill and Gliebe, 2008; Howard and Burns, 2001; Menghini et al., 2010; Raford et al., 2007), the fastest route (Howard and Burns, 2001; Raford et al., 2007), and the safest route (Howard and Burns, 2001).

Methods to generate the alternative routes also varied by the studies. The studies by Altman-Hall et al.(1997), Howards and Burns(2001), Raford et al.(2007), and Dill and Gliebe(2008) used ArcGIS to generate the shortest routes, whereas Menghini et al.(2010) used a multi-agent transport simulation toolkit which keeps iteration of eliminating links until it find a unique shortest route (Rieser-Schüssler et al., 2009).

For the fastest routes, Howard and Burns (2001) calculated the directness of each link of the road network, while Raford et al. (2007) used ‘a combination of angular integration and metric distance values' (p.9) for the fastest cognitive route, which is rather different from the fastest route.

For the safest route, Howard and Burns (2001) used a bicycle stress level for each link of the road network that was developed by Sorton and Walsh (1994). The bicycle stress level was a proxy of perceived safety which was calculated for evaluating a level of service (LOS) of road links using the variables of average traffic volume, speed of traffic and the width of kerb-side lane.

It should be noted that the generated fastest and safest routes did not mean the real fastest or safest routes. For example, the two fastest routes used in the two studies did not use any speed-related values to generate them, but rather were indirectly calculated using the directness and angle of each segment respectively. The difficulty of measuring real trip times and the safety of each segment of the road network could be the reasons that the shortest distance route was popularly adopted and the other alternative route types were not. In spite of the limitations, the comparison between the actual routes and the purpose-generated routes showed the different characteristics of the chosen routes from those generated.

Shortest Vs fastest Vs safest

The comparison between the actual routes and each type of the alternative routes indicated that cyclists did not follow any specific route types but chose a balanced route rather than a skewed one to a specific criterion. On average, about 50% of the segments in the actual routes were overlapped with the segments in the shortest routes (Altman-Hall et al., 1997; Howard and Burns, 2001). In the study of Menghini et al. (2010), and about 35% of the actual route were matched with the shortest routes while the study of Raford et al.(2007) found that none of the actual routes followed the shortest routes more than 60%.

In terms of the comparison between the actual routes and the fastest alternatives, 43.8% of the segments of the actual routes were overlapped with the ones of the fastest routes (Howard and Burns, 2001), while the study of Raford et al. (2007) also found that none of the actual routes followed the fastest routes by more than 60%.

For the comparison with the safest route, although there was only one case, only 20.4% of the segments of the actual routes were overlapped with the ones of the safest routes (Howard and Burns, 2001).

All the studies clearly indicated that cyclists did not follow the shortest route. However, distance seems to be a more influential factor for cyclists' choices than time and safety, as higher overlapping rates were shown with the shortest routes. Respondents in the study of Dill and Gliebe(2008) indicated that 'Minimising distance' was the most important factor for their route choices, and the model estimation in the study of Menghini et al.(2010) found that distance was the most influential factor. However, both studies did not include time as an answer in their questions.

Although distance was more influential than the other factors, cyclists made a balance depending on the environments given to them and were influenced by other factors. The chosen routes by cyclists were not fastest, but faster than the others, as more main roads were included in the actual routes than the others. They were not the safest, but safer as more residential road included than the others; not shortest, but shorter as more common segments were found between the actual routes and the shortest routes than the others (Howard and Burns, 2001).

Raford et al. (2007) found that cyclists did not follow either the shortest route or the fastest route: 46% of the actual routes were similar to the shortest route, while 46% of them were similar to the fastest route. They concluded that although individual cyclists followed one of the two logics for a choice of routes, each of the cyclists had their own logic, and the logic choice could be influenced by many other factors such as personal fitness, demographics, scenic preference etc.

Mengini et al.(2010) also revealed that the conditions of all the other factors considered in the study, except for distance, were better with the chosen routes than the generated routes; less hilly, fewer number of traffic lights, more marked bike paths.

Road types and cycling facilities

The actual route based studies provided a lot of information about the physical characteristics of the chosen routes. Overall cyclists preferred or chose main roads over any other types of roads or streets, while off-road paths were less than 5% (Altman-Hall et al., 1997; Howards and Burns, 2001). However, the study by Dill and Gliebe (2008) showed few different findings from the two studies. It can be seen that 43% of the segments of the actual routes were main roads, while 24% of them were off-road paths. Cyclists in Portland, USA chose main roads as a main route for commuter cycling, but they also chose off-roads significantly more than the two studies.

On the other hand, Dill and Gliebe (2008) also found that ‘Ride on path/trail’ was ranked at 6th in importance among seven factors for route choices for cycling to work/school. From these results, it can be assumed that commuter cyclists will use off-road paths when they are available, but they will not use off-road paths in trade-offs with any other considerable factors.

In terms of cycling facilities, around 51% of the segments of the actual routes had cycling facilities in the study of Howard and Burns (2001). This percentage was higher than the percentages in the shortest, the fastest and the safest routes (39.4%, 34.0% and 28.9% respectively). In the study of Dill and Gliebe (2008), 28% of the segments in the actual routes had cycling facilities, while 24% of the segments in the shortest distance routes had cycling facilities, so there was no significant difference between the actual routes and the shortest routes in the proportion of cycling facilities. However, it should be noted that respondents in Portland also used many off-road paths or similar kinds of paths for cycling. Therefore, overall 52% of the routes were not ordinary roads.

Interestingly, 78.6% of the actual routes obtained in Zurich, Swiss had a bike lane (marked bike paths) (Menghini et al., 2010). When considering access roads to houses usually do not have a bike lane or cycling marks on it, this percentage means that most of road segments of the actual routes have a bike lane. This assumption could be supported by the fact that 68.7% of the shortest paths also had a bike lane.

The findings indicate that cyclists tend to use a route having a cycling facility if it is available. So the presence of cycling facility is an important factor for cyclists’ choices and when good cycling infrastructures are provided, cyclists may choose a route which they can use more facilities with.

Route choice criteria

Unlike the other studies reviewed here, the study of Dill and Gliebe (2008) examined differences in priority of route choice criteria via the different characteristics of cyclists including gender, seasons and frequency of cycling and attitude to safety. There was no difference in the ranks of route choice criteria between males and females. However, female cyclists gave more points to ‘Minimizing distance’, ‘Avoid streets with lots of traffic’, and ‘Avoid hills’. This indicates that females are rather more sensitive to physical environment and traffics.

There were differences in giving priority to route choice criteria by seasons and the frequency of cycling. In summer, frequent cyclists seemed to consider trip time more seriously than less frequent cyclists, while in non-summer, less-frequent cyclists seemed to consider safety more seriously than frequent cyclists. However, the findings had a problem in that the cycling purposes were a mix of utility and leisure, so the different characteristics of leisure cycling and commuter cycling were not considered.

Other differences in the route choice criteria were found with attitudes to the safety of respondents. Respondents who thought that cycling was less safe than using cars gave higher points to the criteria of ‘Ride in bike lane’ and ‘Ride on path/trail’, and lower points to the criteria of ‘Avoid hills’ and ‘Reduce wait time at signs/lights’. This may indicate that cycling facilities would be an important factor for cycling safety and that cyclists who were not confident with safety during cycling might choose a route with facilities. Therefore cycling facilities might improve the perceived safety of cycling.

Hilliness

Hilly areas were generally avoided by cyclists, but this was not an important factor for route choice (Dill and Gliebe, 2008). However, it could be changeable by the level of gradient. Menghini et al. (2010) found that cyclists were affected by a maximum level of gradient, not the average gradient along a route. This is particularly important as most studies have considered the average gradient as a factor. Although feeling hardness with a given gradient would be different depending on the fitness level of individual cyclists, practitioners need to consider a maximum level of gradient along a proposed cycling route. It could be also potentially valuable to examine an acceptable level of gradient of various cyclists.

Discussions

The studies using the actual route data found what routes cyclists actually took and showed various characteristics of the routes, such as distance, cycling facility, road class etc in numbers. Although it can be assumed that cyclists may choose a route which is shorter in distance or has more segments with a bike lane than other routes, we do not know the real reasons that cyclists chose a specific route because none of the previous studies directly asked cyclists why they chose the route or why cyclists did not choose the shortest or safest route that a computer generated. So studies using actual data also need to study why cyclists choose their routes and not the possible alternatives.

The study of Dill and Gliebe (2008) included a questionnaire which asked about the importance of criteria for route choices. This provided a little more information about cyclists' behaviours for route choices than the other studies. However, the study still did not go further inside the thoughts of cyclists, so studies are required to explore the thoughts of cyclists beyond the numbers shown by the actual route data.

Another point with the studies with actual route data is that there would more than one route for a given origin-destination pair (Hillier, 1986). Cyclists can choose one of several available alternatives for their route. Some of them will stick to one route, but others may change depending on different conditions such as the trip purpose of a day, weather, personal conditions etc. The previous studies focused on comparing the chosen routes with computer generated routes only. However, it could be also meaningful to compare a frequently used route with a less frequently used one for the same origin-destination pair or simply compare all the routes chosen by individual cyclists to examine how the trip purpose or any other factors influence choices of the routes.

2.5 Mixed Methods Approach

Quantitative methods tend to dominate cycling studies, especially route choice studies. Although qualitative studies are not rare, they are still less common than purely quantitative studies. For cycling route choices, qualitative studies are found even less. This could be because of the nature of route choice studies, which usually seek mathematical models with explanatory variables.

However, in the other topics in cycling, several studies adopted qualitative methods for them: mode preference (Pooley et al., 2011a, 2011b, 2013), culture influence (Aldred and Jungnickel, 2012; Aldred and Jungnickel, 2014; Jungnickel and Aldred, 2013), characteristics of cyclists (Aldred, 2010; Aldred 2012; Aldred, 2013) etc. The recent popularity of qualitative methods in cycling studies can be explained via how understanding people's behaviours is a key, as the process of making a decision is complex and cannot be explained by only mathematical ways. Understanding behaviours of people is a study at a micro-scale, but the quantitative approach is often not good at explaining this (Pooley et al., 2011a). Otherwise, qualitative methods proved that they are useful in exploring mode choice issues at individual and household levels (Anable, 2005; Horton et al., 2007; Hunecke et al., 2010; Jarvis, 2003; Mackett, 2001 and 2003).

Concerns and values with qualitative methods

The actual concern regarding route choice studies is whether qualitative methods can derive any useful findings differing from the findings using traditional quantitative methods. Unlike mode choice, route choice is much more related to the improvement of a physical environment because many potential influencing factors such as weather or seasons are hardly interventional, whereas physical environments are amendable. So providing preference for potential factors in numbers using quantitative methods would be clearer for generalisation of the findings for policy makers and planners. However, it argues that people in cycling contexts hesitate to make their belief an action because of other constraints (Shove, 2010; House of Lords Science and Technology Select Committee, 2011). Although as few studies have adopted qualitative methods for route choice contexts in cycling, it would be worthwhile to include a qualitative technique into route choice studies for cycling to find something beyond the numbers.

It is rare to find purely qualitative studies in cycling route choice studies, but there are a few studies that have adopted a partially qualitative component. Winters et al. (2010) conducted a study for estimating the influence of built environments in cycling route selections in Vancouver, Canada. They had interviews with 74 participants and collected a typical cycling route for non-recreational purposes from them as well as the reasons that they chose the route for. The reasons that the individual participants mentioned for their chosen route were summarised in Table 2.2. They concluded that cyclists detoured to use designated cycle infrastructures rather than using the shortest path, as well as that the value of safety and comfort of a route were important for their route choices.

Table 2.2 Examples of Respondents' Reasons for Route Choices on Bicycle Trips - Study by Winters et al.(2010)

- Always goes along bicycle routes
- Doesn’t mind going extra distance to stay on bike routes, especially aesthetically pleasing ones
- Selects downtown road with bike lane instead of more direct route without bike lane.
- Takes a longer route to avoid a dangerous on-ramp.
- Selects (off-street) route along dyke because there is no traffic.
- Selects routes through alley instead of busy arterial.
- Does not take shortest route, but safest; rides through regional park in daytime, but not at night.
- Takes route because there is not a lot of traffic, and good shade.
- Avoids climbing steep hills; turns to avoid hills, or narrow or rough roads.
- Changes route often to get favorable hills, and where there are fewer cars.
- Selects route to have less traffic, better scenery, and avoid hills.
- Takes a variety of routes to keep it interesting, along any of the residential streets.
- Rides different routes depending on whether trip is made fast (arterial) or safe (along local road).
- Takes (unpaved) route through the park on the way home, when it is fine to get dirty.

Source : Winters et al.(2010), p.5 and p.7

Although this study was not a full qualitative study, the reasons from the interviews highlighted the potential complexity of reasoning to find a suitable route. This would also show a variety of human behaviours. Cyclists could choose a different route for the same origin and destination by the conditions at the moment of cycling; for example *‘rides through regional park in daytime, but not at night’*. A cyclist chose a different route depending on the time of day and might have two or more alternative routes for their trip. So this indicates three points: firstly the overall preferences of cyclists revealed from quantitative methods may not fully reflect the complex and various choices of individual cyclists; secondly the certain reasons that were relatively less importantly considered in quantitative studies such as comfort, scenery, hilliness etc should not be neglected; thirdly, qualitative methods such as interviews can derive more enriched findings. So, a mixed method approach of qualitative and quantitative methods together can expand a scope of the study and explore different aspects of route choice studies or at least reveal explanations for specific preferences.

Benefits of mixed methods approach

There are a few examples for studies using a mixed approach of quantitative and qualitative methods in cycling studies (Pooley et al., 2011a, 2011b, 2013; Heesch et al., 2012). Pooley et al. (2011a, 2011b, 2013) had conducted a study to understand the nature of cycling and walking in England. The study adopted multi-methods with a range of quantitative and qualitative tools including questionnaires, spatial analysis, interviews and ethnographic methods. The study also compared differences in four cities in England: Worcester, Lancaster, Leicester and Leeds. The study aimed to understand various aspects of cycling as a transport means for short-distance travels so as to provide valuable information for planners and policy makers (only cycling part are presented in the thesis). Regarding route choices, the study also examined the process of making decisions for specific cycling routes, but very little work was reported about route choices.

The study was conducted by four main methods. In terms of quantitative methods, questionnaires collected data on the experience of and attitudes towards cycling (with only 619 usable responses for cycling) while spatial analysis with land uses mapping and the network of all cycling routes was also carried out for four cities to assess the influence of land use and connectivity to level of cycling. For qualitative methods, eighty semi-structured interviews were conducted with participants selected from people who indicated their willingness to participate in the questionnaire. The interviews examined the attitudes to cycling, the motivations for the cycling journey, route selections and the experience of the journey. Household ethnographies were also conducted with 20 households to observe and understand the characteristics of journeys that people make every day within a community. The interviews and ethnographies together generated a large amount of transcripts.

The study showed that quantitative methods and qualitative methods can be complementary to each other. In the spatial analysis (quantitative method), the study examined the correlation between cycling journey frequency and global and local connectivity[2] of the network. However, the spatial analysis did not find any correlation between them. The authors concluded that the

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[2] Global connectivity was defined as an indices of betweenness, closeness and straightness, while local connectivity was defined as indices which included intersection density, network density and an average number of junctions for each section of the network (Pooley et al. 2011b)

connectivity of the street network was an insufficient factor in explaining the cycling use of people in daily activity and that there might be more influential factors to explain that. On the other hand, the qualitative research found the other factor influencing people's choices for daily travel. It revealed that risk from traffic was a major barrier changing from using a car to cycling. It cannot be said that infrastructure is not important, but it is at least less important in mode choice.

There was also the case that the findings from the questionnaire were supported more in detail by the qualitative methods. In this case, the findings from the quantitative research were expressed in numbers; otherwise the findings from the qualitative methods were explained by the descriptions from the participants. For example, the study asked questions about the difficulty of organising journeys involving cycling with other members of the family. The results from the questionnaire showed that around 40% of respondents answered that they used a car to give a lift to their child (or children) and around 30% of them did it for the elderly and someone else. These results clearly confirmed that a chained trip with the other members of the family was often a decisive factor in the choice of modes. The qualitative methods then revealed the reasons for the difficulty of making a journey by cycling with the other members of the family through the descriptions of the respondents. For example, when people need to make a journey with a child or children, it requires more kits for them containing things such as outdoor clothes and shoes than using a car.

A research method utilising either questionnaires or interviews might provide limited aspects or facts only. If the study used a questionnaire only, it could find that trip chaining was an important factor and that there was no correlation between network connectivity and cycling frequency, but it might not find the reasons for the difficulty in making a cycling trip with other family members and how safety was a more important factor. On the other side, if the study used a qualitative method only, they could find that the fact that family members causing difficulty in making a cycling trip and safety concerns was an deterrent to cycling, but it could miss how much trip chaining disturbs choosing cycling for their trip and the relationship between network connectivity and cycling frequency. Therefore using quantitative and qualitative methods together will cover the weaknesses of each approach and enrich the findings, revealing different points of view and something that might be lost by using one method only.

2.6 Chapter Summary

This chapter reviewed core factors influencing cycling route preferences (and partially mode choice), various studies for segmentation of cyclists, stated preference studies and studies using actual data, especially about using GPS and GIS, as well as the benefits and justification of using qualitative methods together with quantitative methods for route choice studies.

The factors influencing cycling route choices were categorised based on the previous studies into six categories including physical environment, traffic environment, cyclist characteristics, natural Environment, trip characteristics and cyclist concerns.

Some of the findings from the previous studies were consistent, but others were inconsistent in the preferences, especially with cycling facilities. In addition, cycling facilities and road types were popular studies, but the others were covered a lot less. In terms of cycling route studies in England they were rather out-dated, and the behaviours of people keep changing. Therefore it is required to re-examine the importance and preference with various influencing factors for cycling route choices for English cases.

The review also found that different cyclists will behave in different ways. For route choices, cyclists will have different preferences and attitudes towards the route factors. The review also showed that there is a high potential for the study with demographic variables such as gender. Experience of cycling and comfort level were also interesting variables which may show differences in choices. Furthermore, a factor-cluster analysis may provide segments of cyclists based on non-demographic variables which represent different cyclists’ attitudes and behaviours towards route selection.

To date, many studies were conducted using SP methods. The studies provided good ideas about what factors or features were more preferred. SP studies were good at testing non-existing features, whereas RP studies dealt with what cyclists actually chose and showed the characteristics of the chosen studies.

The previous studies using actual data showed that it will enhance and cross-validate findings from the studies using SP methods. However, few studies using actual route data have been done for cycling route choices in England. In other countries, using GPS and GIS for comparative studies with actual route data had already been conducted.

Not many studies were carried out using qualitative methods, but the number of studies using them are increasing. The recent trend in cycling studies is to understand the behaviours of people at an individual or household level. The qualitative approach provided useful techniques for finding explanations for the behaviours of people. Even for cycling route choice studies, understanding the reasons for the choices of individual cyclists is important in finding real preferences. Therefore, using mixed methods will be promising in revealing both the choice behaviours of cyclists for their routes and the reasons for the choices together.

Several conclusions can be drawn from the literature review:

1. A lack of showing the whole picture about route choices by cyclists in England

   The previous studies focused on cycling facility and road types so the other factors were given relatively less attention. Junctions and the natural environment can be included in this neglected field. Many potential variables should be examined equally and compressively.

   Safety is an important factor in cycling studies. However, for route choices, safety was not clearly investigated. There is a lack in what features are related with safety matters. It is known that traffic is a core source for feeling risk during cycling. However, what features within traffic cause this have not been clearly studied yet, so more studies that probe the relationship between safety and the other route features should be carried out.

   The route choice studies were rather outdated with the cases in England. There were a few studies which were carried out in English cities; however, all of them were done during 1990s. Since then there have been many changes to cycling environments and the atmosphere, so re-examining the factors influencing route choices of cyclists should be conducted for English cases.

2. A lack in reflecting differences in the characteristics of cyclists in terms of preferences and choices

   It is obvious that the characteristics of cyclists influence the preferences and choices for routes. However, not many studies have tested the differences via the characteristics of cyclists in terms of route preferences. Gender showed the most significant differences in the cycling behaviours, so it should show significant differences in route choices as well.

All of the studies for route choices were carried out for a single case area with different factors. However, mode choice studies or cultural studies for cycling such as Pooley et al. (2011b) were carried out in multiple cities and the findings were compared. Route choice studies should be also carried out with multiple cases for a comparative analysis of cyclists' choices and preferences. This is directly related to examining the influence by regional variations in cycling environments.

More importantly, there have been several studies which classified cyclists. Such segments showed different aspects of cyclists' characteristics. However, there is no such study for route choices, so developing cyclist types for route choice will be worthwhile in understanding the various characteristics and preferences of different cyclists.

3. A lack in studies with the actual routes chosen by cyclists

   There were very few studies carried out with actual route data for English cases. Most of the studies for route choices were carried out using the SP method and focused estimating the values of variables such as cycling lanes. The studies using actual route data provided valuable information about the chose routes, such as the proportion of each of the road types and facility used, as well as trip mileages and speed etc. Moreover, cyclists have two or more alternative routes for the same origin and destination, but the choice seems different by trip purposes. So it is an interesting study to compare actual routes by trip purposes rather than to compare actual routes with generated routes.

4. A lack in probing the reasons for the choices of cyclists for the routes

   All of the route choice studies examined what features were preferred or chosen and showed the results in numbers. However, they did not explain why cyclists chose their specific routes. To explain why cyclists do this, it is necessary to understand their attitudes and opinions on an individual level; however, quantitative methods are weak in investigating behaviours or perceptions of cyclists at the individual level.

   Several studies using qualitative studies have already been conducted in the other parts of cycling studies, especially for cultural aspects and mode choices. Therefore it is worthwhile to use qualitative methods to probe the opinions of cyclists about cycling routes at an individual level and examine what qualitative approaches can derive for route choice studies which are different from quantitative approaches.

The literature review has given rise to 5 research objectives and 8 sub-objectives:

Objective 1*: Investigate the factors which influence the choices of cyclists for routes*

Sub-objective 1-1: Investigate the influencing factors regarding the 3 categories: physical, traffic and natural environment

Sub-objective 1-2: Investigate the feeling of unsafety of cyclists in regards to the route features

Objective 2*: Investigate variations in the attitudes to the factors by the characteristics of cyclists*

Sub-objective 2-1: Develop typologies of cyclists using confidence level and route choice criteria

Sub-objective 2-2: Investigate variations by four characteristics of cyclists: gender, city and the cyclist types by confidence level and route choice criteria

Objective 3*: Investigating the features of the actual routes that cyclists currently use*

Sub-objective 3-1: Investigate the characteristics of the actual routes

Sub-objective 3-2: Investigate differences in the characteristics of the actual routes by trip purposes

Objective *4: Investigate the reasons for the choices of cyclists based on actual routes*

Sub-objective 4-1: Probe the reasons for the choices of cyclists based on actual routes

***Objective 5**: Integrate and interpret the findings*

Sub-objective 5-1: Reconstruct comprehensive behaviours of cyclists for route choice using the findings from quantitative and qualitative methods

Chapter 3 Methodology

3.1 Introduction

Chapter 3 describes the methodology to address the research objectives presented in section 1.3 (see Table 3.2). The study aims to probe the influencing factors in preference and importance as well as look at the actual choices and the reasons behind them. The study requires a comprehensive approach to addressing the different natures of the research objectives.

The study adopts a mixed methods approach, which is useful for addressing confirmatory and exploratory questions at the same time, has better inferences and provides the chance to look at various views (Teddlie and Tashakkori, 2009). Mixed methods research is not yet concretely defined and is still developing its theory and designs and ways of implementation. However, the way of using the two opposite types of methods, quantitative and qualitative, will address the objectives raised for this study.

The chapter explains the methods chosen and the justification for these choices. The chapter starts with a brief introduction of the mixed methods approach in section 3.2 and is followed by the overview of study design (section 3.3). Study areas and samples are then explained in section 3.4. The methods used for the study (section 3.5-3.7), the research ethics (section 3.8) and limitations of the used methods (section 3.9) then follow.

3.2 Mixed Methods Approach

The world cannot be explained simply through either numbers or words. Well planned mixed approaches of quantitative and qualitative methods will allow deep and credible understanding of real world contexts (Miles et al., 2014).

Understanding people’s preferences and choices belong to the field of social sciences. Route choice studies for cyclists are also a part of social science. In social science, the methodologies are broadly divided into three approaches: quantitative, qualitative, and the mixed methods approaches. The first two approaches are more common and have a longer history in social science, so they have a stronger foundation in various aspects such as fundamental theories and methods. The mixed methods approach was born as an alternative way after the great debates between quantitative and qualitative sides, and they use quantitative and qualitative methods together in a single or series of studies for better understanding about people and social phenomena (Greene, 2007; Teddlie and Tashakkori, 2009).

The quantitative approach describes a phenomenon with numbers in general, so this approach emphasises measurement of variables, the search for relationships between variables and tests research hypotheses with a large number of samples (Gravetter and Forzano, 2012). An analysis utilising a quantitative approach is conducted in statistical ways to prove patterns in the behaviours of people. This approach with appropriate techniques is good at explaining and comparing revealed phenomenon, generalising the findings, determining influencing variables and predicting what will happen. However, quantitative approach has a difficulty in finding new phenomena because the approach is descriptive and focused the generalised relationships between variables. The approach will be often carried out in an unnatural environment or biased with pre-set questions and answers.

On the other hand, the qualitative approach focuses on meaning, understanding and interpreting situations (McMillan, 1996). The qualitative approach generally requires a smaller size of samples, but it also gathers deeper and detailed data including emotions or unexpected facts (Bryman, 1988; Quinn Patton, 1990). However, the approach has limitations in reliable generalisation across cases or observations (Kirk and Miller, 1986), examining relationships between cases or observations (Morse, 1994) and drawing definitive conclusions.

This thesis proposed using a mixed method approach at the end of the literature review. Tashakkori and Creswell (2007) defined mixed methods research as ‘research in which the investigator collects and analyses data, integrates the findings and draws inferences using both qualitative and quantitative approaches or methods in a single study’ (p.4). However, there is still inconsistency in the definition and the scope of mixed methods among researchers (Bryman, 2007; Sandelowski, 2001; Tashakkori and Creswell, 2007), and the definition of mixed methods research is not yet confirmed and still evolving (Johnson, et al., 2007; Tashakkori and Creswell, 2007). Despite a rather unsettled definition, the key to the mixed methods approach is to use both quantitative and qualitative methods together in a single study. The concern is a matter of the degree of integration of the two methods (Johnson, et al., 2007).

Why do researchers use or need to use a mixed methods approach? This is still an on-going issue. Many researchers conduct mixed methods research for breadth, corroboration or both (Johnson et al. 2007). Breadth includes providing a fuller picture, better and deeper understanding and enhancing description and understanding while corroboration means providing triangulations of the findings (Johnson et al. 2007). These purposes are closely related with research questions, which a researcher makes a plan for a study with. Tashakkori (2006) argued that the research question drives the mixed methods approach. Greene (2007) also argued that the methods for social science are selected by the purposes and questions of research, so mixed methods are used in fulfilling the purposes and questions of research.

In terms of transport sector and understanding people's behaviours, how people make decisions and organise their trip is emphasised (Goulias, 2003). One of the ways to improve understanding the behaviours of people is to attempt studies with mixing a quantitative approach and qualitative approach. Grosvenor (1998) pointed out that qualitative methods were useful for understanding the hidden motivations, attitudes and perception behind people's travel behaviours. Clifton and Handy (2003) also argued that qualitative methods were powerful tools in allowing researchers to understand complex travel behaviours when used either with quantitative methods together or alone: they would identify the important variables to be included in the survey before the survey, while they would also provide explanations for the survey results.

It is clear that the qualitative approach will enhance understanding of other aspects of the behaviours of people. Mixed uses of quantitative and qualitative methods are not uncommon in social research. Many studies have already been done by using both quantitative and qualitative methods together without mentioning the mixed methods approach (Greene, 2007). However, this approach is still not common in the transport sector. This thesis attempts to seek out the reasons for the choices of cyclists as well as the influencing factors for route choices and the characteristics of chosen routes. Therefore the mixed methods approach is suitable for addressing the research aims.

In terms of the design of mixed methods research, Creswell and Plano Clark (2011) proposed prototypical versions of six designs: convergent design, explanatory design, exploratory design, embedded design, transformative design and multiphase design. Table 3.1 presents the key characteristics of the designs. The research designs will guide what methods a researcher

Table 3.1 Prototypical Characteristics of the Major Designs of Mixed Methods Research

Characteristics	Convergent	Explanatory	Exploratory	Embedded	Transformative	Multiphase
Definition	Concurrent data collection and separated analysis	Starting with quantitative phase, followed by qualitative phase	Starting with qualitative phase, followed by quantitative phase	Use of supporting data either quantitative or qualitative before, during or after major data collection procedure	Explanatory design or alternative one within transformative, theoretical framework	Combining concurrent and/or sequential collection over multiple phases of a programme
Purpose	Complete understanding Validate or corroborate quantitative scales	Explain quantitative results	Test or measure qualitative exploratory findings	Preliminary exploration before an experiment More complete understanding during an experiment Follow- up explanations after an experiment	Identifying and challenging social injustices	Implementing multiple phases to address a programme objective
Interaction	Independent	Interactive	Interactive	Interactive	Interactive	Interactive
Priority of strands	Equal emphasis	Quantitative emphasis	Qualitative emphasis	Either quantitative or qualitative emphasis	Equal, quantitative or qualitative emphasis	Equal emphasis
Mixing strategies	Merging: After separate data analysis With further analysis of separate results	Connecting: From quantitative to qualitative data collection Use quantitative results for qualitative phase	Connecting: From qualitative to quantitative data collection Use qualitative results for quantitative phase	Embedding one type with the other type: Before, during, or after major component Use secondary results to enhance primary strand	Mixing within a theoretical framework: Merging, connecting or embedding the strands within a transformative theoretical frame	Mixing within a programme-objective framework: Connecting and possibly merging and/or embedding within a programme objective

Source: Adopted from Creswell and Plano Clark (2011, p. 73) needs to choose to ensure credible and reliable results and to make the study manageable (Creswell and Plano Clark, 2011).

On the other side, Maxwell and Loomis (2003) argued that ‘typology the actual diversity in mixed methods studies is far greater than any typology can adequately encompass’ (p. 244). However, Teddlie and Tashakkori (2009) pointed out that it is important to establish ideal types of the designs of mixed methods research to allow researchers to creatively adjust the designs to fit to a given environment or purpose of research. Therefore it is essential to be flexible and creative in study designs to best fit the purposes of the study.

3.3 Overall Design of the Thesis

The thesis is explanatory in nature as the aims of the study are to identify significant factors in phenomenon, for the thesis, choices and preferences and to explain why the choices and preferences occur. Table 3.2 shows the objectives of the thesis with data collection methods and analysis strategies.

The study adopts the explanatory sequential design in which the data collection and analysis for quantitative data takes place first and is then followed by the data collection and analysis for qualitative data (Creswell and Plano Clark, 2011). The purpose of this design is to find the results from the qualitative phase to support the findings from the quantitative phase. In addition, this design also allows findings to be somewhat new from the qualitative method and different from the quantitative method.

Table 3.2 Research Objectives and Methods for Data Collection and Analysis

Stage	Objectives	Research Approach	Data collection Method	Analysis Method
Phase 1	Objective 1-1. Investigate the influencing factors regarding the 3 categories : physical, traffic and natural environment	Quantitative	Questionnaires	Descriptive statistics
	Objective 1-2. Investigate feeling unsafe of cyclists to the route features	Quantitative	Questionnaires	Descriptive statistics
	Objective 2-1. Develop typologies of cyclists using confidence level and route choice criteria	Quantitative	Questionnaires	Factor analysis/ cluster analysis
	Objective 2-2. Investigate variations by four characteristics of cyclists: gender, city, and the cyclist types by confidence level and route choice criteria	Quantitative	Questionnaires	Descriptive statistics
Phase 2	Objective 3-1. Investigate the characteristics of the actual routes	Quantitative	GPS data collection	Descriptive statistics
	Objective 3-2. Investigate differences in the characteristics of the actual routes by trip purposes	Quantitative	GPS data collection	Descriptive statistics
Phase 3	Objective 4-1. Probe the reasons for the choices of cyclists based on actual routes	Qualitative	Interviews	Within-case analysis/ Cross-case analysis
Interpretation	Objective 5-1. Reconstruct comprehensive behaviours of cyclists for route choice using the findings from quantitative and qualitative methods	-	-	Integrating findings

The design of this study is rather modified from the typical explanatory sequential design. Figure 3.1 shows the flow of the thesis process. The thesis consists of three phases: questionnaires, actual route collection and interviews. The data for the first and second phases are quantitative while the data for the third phase is qualitative. Phase 1 is an almost independent phase while phase 2 and 3 are related to each other.

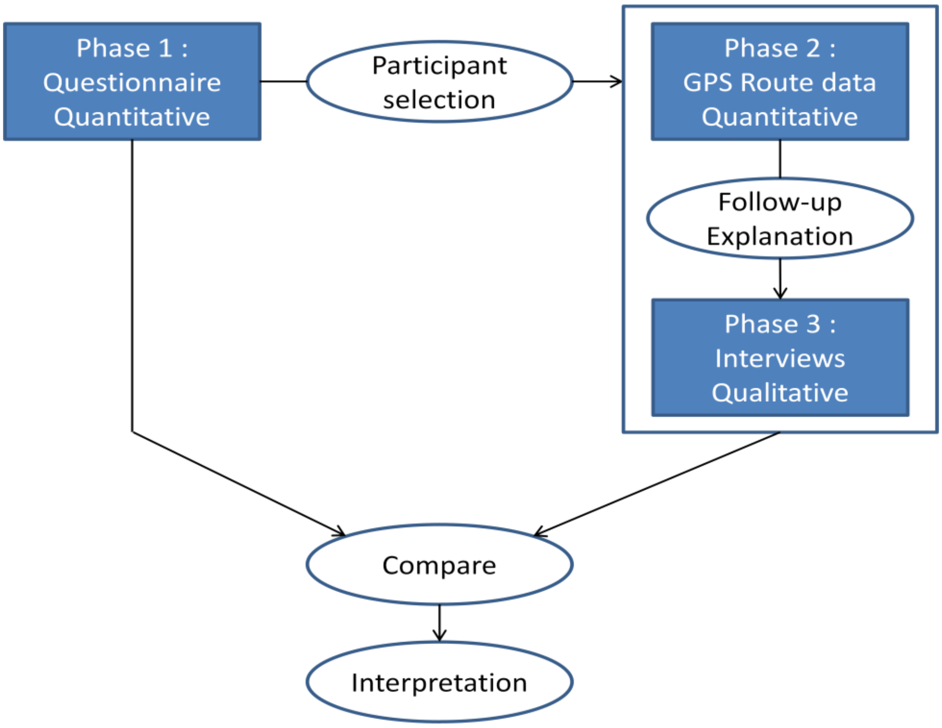

Figure 3.1 Design of the study

Phase 1 provides only a list of potential participants for the second and third phases, and most of analysis in phase 1 is independently carried out, whereas, the results from phase 2, the GPS route data, is important because the purpose of the interviews, phase 3, is to probe the reasons for the observed choices in phase 2. The design for phase 2 and 3 is the typical explanatory sequential design. However, the design for phase 1 and phase 2-3 are the convergent parallel design but slightly amended. At the end of the process, the findings from phase 1 and phase 2-3 are compared and the results are interpreted together.

3.3.1 Methods used in the Thesis

Mixed methods research requires two different types of data. Teddlie and Tashakkori (2009) suggested six key strategies for data collection for mixed methods research, which included questionnaires, interviews, focus groups, tests, observation and unobtrusive measures. Table 3.3 shows the relative strengths and weaknesses of each strategy. The strategies can collect both quantitative and qualitative data, and researchers can use one strategy or two or more strategies to collect both types of data (Teddlie and Tashakkori, 2009).

The thesis collected two quantitative samples of data and one qualitative sample. The first phase needs to collect general attitudinal data to route features for a large number of samples so questionnaires are feasible. Questionnaires have strengths in time, costs and amounts, and they allow the respondent to rank given variables by importance or priority (Teddlie and Tashakkori, 2009). However, questionnaires also have weaknesses in missing data, low response rates and misunderstanding of questions (Johnson and Turner, 2003). Moreover, there is possibility that some respondents may distort them (Gravetter and Forzano, 2012).

The data for the first phase includes many variables to be tested as the phase needs to identify what factors more or less influence the choices of cyclists. Analysis results of the questionnaire will become a basis for choosing suitable participants for the second and third phases. Questionnaires allow for collecting many samples of lots of variables with relatively low costs within limited times.

Interviews are also good at measuring the attitudes of people. However, interviews usually focus on in-depth information, so it is not feasible to use interviews for collecting attitudes towards many potential items all together. Furthermore, interviews with a small number of participants are best for exploring unknown topics or explaining the findings from an earlier part of the research (Gill et al., 2008; Johnson and Turner, 2003).

The second phase requires actual route data which should be usually reported by participants themselves unless researchers keep following and recording their trips. The thesis proposes using GPS to record the routes that participants ride on. This method is a sort of observation, which is an important strategy in collecting information on what people actually do in natural or structured environments (Johnson and Turner, 2003). Using GPS technology for a travel behaviour study has a great advantage in measuring the precise space-time attributes of a target (Asakura and Hato, 2009).

There are several ways to collect travel data including questionnaire surveys, stated preference surveys and using travel simulators. However, all the

Table 3.3 Strengths and Weaknesses of Six Strategies for Data Collection for Mixed Methods Research

Strategies	Strengths	Weaknesses
Questionnaires	• Good for measuring attitudes and eliciting other content from research participants • Inexpensive • Quick turn around	• Must be kept short • Might have missing data • Response rate possibly low for mail questionnaire
Interviews	• Good for measuring attitudes and most other content of interest • Allow probing by the interviewer • Can provide in-depth information	• In-person interviews expensive and time-consuming • Possible reactive and investigator effects • Data analysis sometimes time-consuming for open-ended items
Focus groups	• Useful for exploring ideas • Allow study of how participants react to each other • Allow probing	• Sometimes expensive • May be dominated by one or two participants • Data analysis sometimes time-consuming
Tests	• Can provide good measures of many characteristics of people • Instruments usually already developed • Wide range of tests available	• Can be expensive • Possible reactive effects • Sometimes biased against certain groups of people
Observation	• Allow one to directly see what people do without having to rely on what they say they do • Can be used with participants with weak verbal skills • Good for description	• Reasons for behaviour possibly unclear • More expensive to conduct than questionnaires and tests • Data analysis sometimes time-consuming
Unobtrusive measures	• Unobtrusive, making reactive and investigator effects very unlikely • Can be collected for time periods occurring in the past • Available on a wide variety of topics (archived research data)	• May be incomplete because of selective reporting or recording • Data possibly dated • Data analysis sometimes time-consuming

Source : Johnson and Turner(2003, pp. 306, 308, 310, 312, 315, 317); Teddlie and Tashakkori (2009, p. 233) methods mentioned collect data in virtual or hypothetical environments (Asakura and Hato, 2009). A questionnaire-type survey is an alternative way for the travel data collection which asks participants to record travels during a given period (usually one day). This method can be usually conducted by various instruments such as internet surveys, questionnaires and telephone interviews (Stopher and Greaves, 2007). However, this method has a few problems; for example, burdens on collecting multi-day data and failures of memorising trips which is a significant weakness of this method: individual participants may not accurately remember their trips and there could be errors and mistakes in their descriptions, while some people do not want to report certain trips (Axhausen, 1998).

On the other hand, Griffiths et al. (2000) pointed out that using GPS technology (when especially linked to GIS) could improve the amount, details and accuracy of the travel data as well as almost completely remove the burden from respondents. Moreover, underreporting problems can be improved by using GPS (Schönfelder et al., 2006; Stopher, 2008; Wolf et al., 2003).

However, there is also a weakness with GPS data collection. GPS machines usually do not collect any related data which may be of interest to a researcher (for example, transport modes which are not recorded) but may be important (or need to be distinguished). Therefore many researchers do a recall survey to check inaccurate data and to obtain further information. However, this process is expensive and time-consuming (Bolbol et al., 2012).

Despite the weakness, at least for this thesis, using GPS for data collection for actual routes is beneficial because GPS allows for multi-day data collection with minimum burdens on participants to discover possible variations in their routes for comparisons. Moreover, using GPS is more accurate and less of a burden on participants than conventional ways. If conventional ways, such as a travel diary, is used, participants need to remember and record their trip for several days.

The third phase adopts interviews for qualitative data. Interviews are one of the most common data collection methods for this kind of information (Legard et al., 2003). Interviews are basically a conversation between an interviewee (or interviewees) and interviewer with purposes (Berg, 2009). Interviews usually provide a chance to explore a topic in depth with richness and detail on an individual level, providing a chance to find new insights.

The thesis tries to find the reasons for the choices identified in the second phase. The route choices happens on an individual level, so interviews are better than a focus group. Both methods are good at understanding the factors which influence the decision making of people and behind observed travel behaviours (Clifton and Handy, 2003). However, a focus group is best for exploring the perception of people as a group (which share interests about a specific topic) rather than individuals (Krueger and Casey, 2000).

Expensive costs and time-consuming for analysis are the weaknesses of interviews that are commonly mentioned. Although sample sizes for interviews are generally small, interviews require a lot of effort and time for arranging meetings and conducting interviews before transcribing the recorded data and analysing it. However, most methods have similar problems when they attempt collecting qualitative data. These problems are weaknesses only when comparing quantitative methods.

Another weakness of interviews is that the quality of the data depends on the interviewer's skills and experience. Participants often do not say what they really think or feel when they do not trust an interviewer. During an interview an interviewer needs to make their respondent feel comfortable saying what he thinks about a topic, but also the interviewer should not make them say something that the interviewer may want as it could lead to a serious bias in the data.

3.4 Study Areas and Samples

3.4.1 Study Areas

Two case study cities were considered to represent English cities with contrasting cycling activity and environments according to three key criteria below:

1. Significant differences in utility cycling activities
2. Different physical geography and cycling environments
3. Easy to access for the data collection and interviews phases

For the first criterion, candidate areas were listed based on the rate of cycling to work in the 2011 census data. Figure 3.2 shows that the rate of cycling to work in the cities and towns (DfT, 2013b) of Cambridge, Oxford, York, Kingston upon Hull etc. in 2011. These places belonged to the group with a high rate of cycling to work, while most of the other areas in England belonged to the group with a low rate of cycling to work. York had a high rate of cycling for commuting at 7.5% in 2011, while Leeds had a low rate of 1.1%, which is lower than the average percentage of cycling to work in England, which was 1.9% in that year (DfT, 2013b).

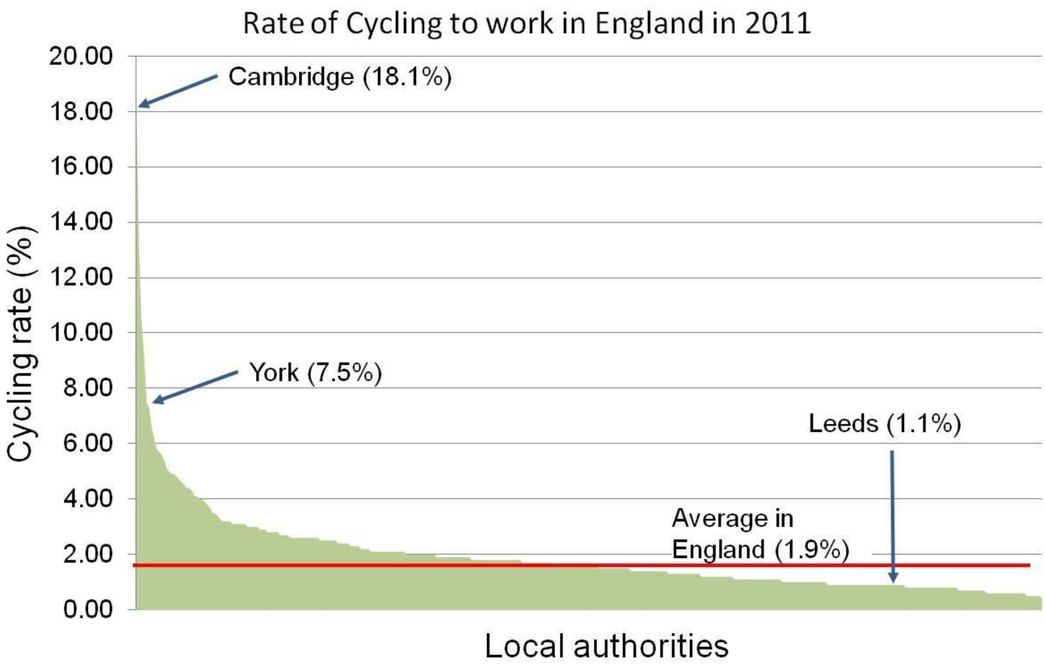

Figure 3.2 Rate of Cycling to Work of Local Authorities in England in 2011 (DfT, 2013b)

The characteristics of the two cities in the geography and cycling infrastructures or the environment were then examined. The populations of Leeds and York are 751,485 and 198,051 respectively. Leeds is a big city for England, while York is a medium one.

Figure 3.3 shows topographies of the cities, and they are clearly contrasting. York is clearly flatter than Leeds: the city centre area of Leeds, which is indicated by a blue circle, is relatively flat but surrounded by hilly terrains, whereas the central area of York in a blue circle is also lower than the surrounding areas. However, the difference between the centre and surrounding areas is small. Therefore Leeds and York are the good study areas to examine influences of geographical differences (hilliness) on cycling route choices.

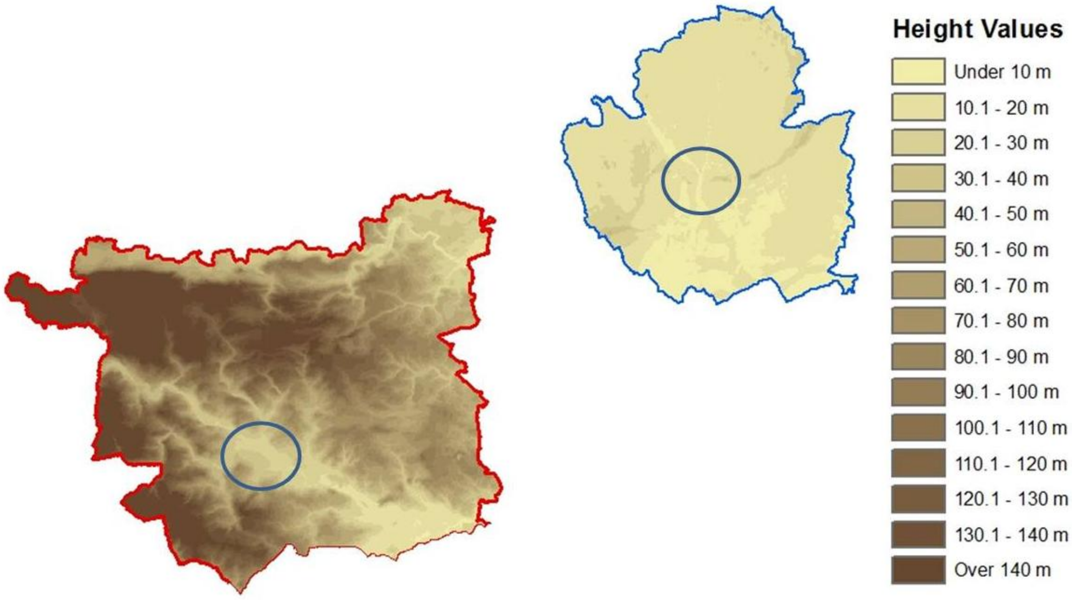

Figure 3.3 Topography of Leeds and York (Data source: Digimap: OS DTM data, 2013)

In terms of cycling infrastructures available, York has more than Leeds both in the total length of the facilities and the percentage of the facilities against total road length (Parkin, 2004). The only exception is shared bus lanes, which Leeds has more of than York, but shared bus lanes are basically for bus use and not for cycling. These differences in cycling infrastructures are one of the reasons to select the two cities for comparing different environments for cycling: one represents a car-oriented city while the other represents a cycling-oriented one.

Table 3.4 Cycling Facilities in Leeds and York

District	Signposted route	Cycle lane	Shared bus lane	Off-road	Road length
Leeds	13.40(0.5)	18.00(0.6)	5.20(0.2)	43.70(1.5)	2,923.8
York	32.20(3.9)	57.30(7.0)	1.90(0.2)	78.20(9.5)	823.9

Unit: km
( ): % against total road length
Source: Adapted from Parkin (2004)

York and Leeds are closely located each other at just 30 minutes away by train. This is greatly beneficial to the author for data collection and conducting interviews as the author is located in Leeds.

3.4.2 Samples

The study intends to use mixed methods, so the sampling methods also include both quantitative and qualitative types. There are many techniques for sampling. Probabilistic sampling and Non-probabilistic sampling are two basic categories in quantitative research (Gravetter and Forzano, 2012), while purposive sampling is one of the sampling methods commonly used for qualitative research (Teddlie and Tashakkori, 2009). However, this categorisation does not always stick to the specific type of research. Purposive sampling methods are also non-probabilistic methods. However, for convenience, the sampling techniques that are used mainly for qualitative research are grouped separately from non-probabilistic methods. Table 3.5 presents probabilistic methods for quantitative research, non-probabilistic methods for both quantitative and qualitative research and purposive methods for qualitative research.

The study aims to understand the behaviours of cyclists for commuting and utility cycling, so the target groups for the samples include utility and commuter cyclists.

The study includes three different phases for data collection: questionnaires, GPS route collection and interviews. However, for the sampling process, only two sampling methods for the two sampling stages were used: the questionnaire stage and the stage of the GPS route collection and interviews. The interviews were conducted with the participants who participated in the GPS route collection.

A convenience sampling method in non-probabilistic sampling was principally adopted for the questionnaire survey, while a typical case sampling method in purposive sampling was used for the GPS route collection and interviews.

The sampling method for the questionnaires is non-probabilistic. Simple random sampling will be ideal at least for the quantitative data (the questionnaire). However, there are a few problems in collecting such data with simple random sampling or other probabilistic sampling methods. Probabilistic sampling methods require the condition that the exact size of the population is known (Gravetter and Forzano, 2012). However, it is hard to know the exact numbers of the target population of commuting and utility cyclists. The Department for Transport provides statistical data for commute cycling only and census data provides data for utility cycling and the rates for commute cycling. However, depending on the sources, the rates are slightly different. So, although it is possible to assume approximate proportions of

Table 3.5 Sampling Methods for Quantitative and Qualitative Data

<table>
<tr><th colspan="2">Category</th><th>Method</th><th>Research type</th></tr>
<tr><td colspan="2" rowspan="5">Probabilistic sampling</td><td>Simple random sampling</td><td rowspan="5">QUAN</td></tr>
<tr><td>Systematic sampling</td></tr>
<tr><td>Stratified random sampling</td></tr>
<tr><td>Proportionate stratified random sampling</td></tr>
<tr><td>Cluster sampling</td></tr>
<tr><td colspan="2" rowspan="2">Non-probabilistic sampling</td><td>Convenience sampling</td><td rowspan="2">QUAN/QUAL</td></tr>
<tr><td>Quota sampling</td></tr>
<tr><td rowspan="14">Purposive sampling</td><td rowspan="6">Sampling to achieve representativeness or comparability</td><td>Typical case sampling</td><td rowspan="14">QUAL</td></tr>
<tr><td>Extreme case sampling</td></tr>
<tr><td>Intensity sampling</td></tr>
<tr><td>Maximum variance sampling</td></tr>
<tr><td>Homogeneous sampling</td></tr>
<tr><td>Reputational sampling</td></tr>
<tr><td rowspan="4">Sampling special or unique cases</td><td>Revelatory case sampling</td></tr>
<tr><td>Critical case sampling</td></tr>
<tr><td>Sampling of political importance cases</td></tr>
<tr><td>Complete collection</td></tr>
<tr><td rowspan="4">Sequential sampling</td><td>Theoretical sampling</td></tr>
<tr><td>Confirming and disconfirming cases</td></tr>
<tr><td>Opportunistic sampling</td></tr>
<tr><td>Snowball sampling</td></tr>
</table>

Source: Adapted from Teddlie and Tashakkori (2009) and Gravetter and Forzano (2012) cycling for commuting or utility, they do not mean that the proportions are the same as the actual proportions of cyclists in a target city.

Another problem is the efficiency of sampling work. When the population is widely distributed over a target area, it will cost a lot of time and efforts (Gravetter and Forzano, 2012; Teddlie and Tashakkori, 2009). This matter is again related with the uncertainty of the target population. It is also very difficult to know where the cyclists suitable for the thesis are and to make a complete list of them including required information such as names and addresses etc. In addition, there is a lower possibility of meeting suitable individuals who cycle for commuting and utility purposes on the street or any other places than the other transport user groups, such as pedestrians, drivers or public transport users, in the countries having a low cycling use rate. So by this reasoning, using non-probabilistic methods is better in easiness, costs and time than probabilistic sampling methods and more commonly used for behaviour research (Gravetter and Forzano, 2012).

The convenience sampling method is the technique that simply takes easy individuals based on their willingness to take part of the study. The collected samples have a high possibility of being biased and of not representing the population, so the thesis makes efforts to reduce this bias via collecting samples from several different locations through the case study cities and by two different collection ways: on-street and on-line distribution. However, it is still obvious that this sampling method does not guarantee that the obtained samples will represent the whole population, so a clear description about how the sampling work proceeded and who they are is provided in section 3.5.3 and 4.2 in an effort to reduce the bias (Gravetter and Forzano, 2012).

For the stage of sampling for the GPS routes data and interviews, a typical case sampling method in purposive sampling was adopted. The purpose of sampling is to choose representative cases for each of cyclist types which are developed for the thesis (see section 4.3 for details), so typical case sampling is suitable for achieving representativeness.

Participants were selected among the respondents of the questionnaire survey. Analysis of the questionnaires identified respondents' confidence levels, and potential participants were divided into four groups according to that. Emails, text messages and letters were sent to individual respondents who belonged to one of the groups and agreed to participate in further studies. The sampling tried to recruit a balanced number of cyclists through confidence level, genders, criteria types and cities which were identified from the analysis of the questionnaire survey.

The procedures of the data collections are presented in section 3.5.3. and 3.6.2.

3.5 Phase 1 : Questionnaires

There are 4 common types of questionnaire survey: the mail survey, telephone survey, person-to-person survey and internet survey, and each type has advantages and disadvantages (Table 3.6).

Table 3.6 Advantages and Disadvantages of 4 Common Quantitative Surveys

Survey type	Advantages	Disadvantages
Mail	• Relatively low cost • Less biasing error without interviewer influence • High degree of anonymity • respondents can take time for their answers • Have a moderate to high investment in the research topic	• Relatively simple and easy questions required • No guarantee for surveys fully completed • Low response rates • No interviewer, respondents cannot be probed
Phone	• Moderate cost • High response rate • High quality of data depending on interviewer • Flexible	• Moderate cost • Trained interviewers required • Difficulty with sensitive topics over the telephone • Early termination of interview before completion • Lack of visual materials
Person to person	• High response rate • Flexibility in the questioning process • Allow probing and clarification • Control of the interview situation • Collecting supplementary information	• High cost • Time consuming • Trained interviewers required • Bias due to interviewer's characteristics and techniques • Lack of anonymity
Internet	• Low costs • Automation and real-time access • Less time needed • Convenience for respondents • Design flexibility • No interviewer, respondents may be more willing to share information	• Limited sampling and respondent availability. • Possible cooperation problems • No interviewer, respondents cannot be probed

Sources: Adapted from Frankfort-Nachmias and Nachmias, 1996; Mangione, 1998

The thesis used a mail survey and internet survey together to maximise responses and minimise costs. However, the mail survey was slightly amended to adopt a feature of the person-to-person survey. Potential respondents for the survey were contacted personally on streets and asked to return a completed form by post. The questionnaires were distributed to cyclists on the streets in the cities because it was not possible to obtain their addresses. The phone survey was rejected at an early stage of consideration because it was considered inconsiderate to ask a large number of questions over the phone.

3.5.1 Variables measured

The literature review in Chapter 2 reviewed previous studies which examined various features of cycling routes and cycling behaviours. In Chapter 2 factors affecting cycling route choice were categorised into 6 categories (see Table 2.1). Based on the categorisation, most of variables tested in the thesis were selected from physical, traffic and natural environments.

However, the variables were re-categorised into three groups: cycling facility, road and traffic circumstances and junctions. Cycling facility has various types to be examined for preferences so it is separately grouped, while junctions also have a few different types and behaviours at a junction are of particular interest for safety issues. The other variables were all grouped into road and traffic circumstances.

The variables which measure feeling unsafe were selected from the variables of road and traffic circumstances. The variables under trip characteristics and cyclist concerns (trip distance, trip time and safety) were used as criteria for route choices. Reliability and comfort/pleasantness were also used as criteria for route choices which were used in the previous studies (Bovy and Bradley, 1985; Dill and Gliebe, 2008; Hopkinson and Wardman, 1996; Van Shagen, 1990; Westerdijk, 1990;). Cyclist characteristics were also included in the questionnaire, as usual.

Table 3.7 Measured Variables to Assess Attitudes of Cyclists regarding Route Choices

Category	Road and traffic	Cycling facilities	Junctions	Route choice criteria
Features	Traffic volume Traffic speed Bus lane and service Heavy goods vehicle(HGV) Vehicle parked on street Lane width Gradient Surface quality Icy surface in winter Scenery Street lighting Personal or area security Traffic calming Off-road path Cycling facility	Cycle lanes Segregated cycle paths Shared paths with pedestrian On-road cycle lane(shared with vehicles) Shared lane with buses Off-road paths A bridge with a facility only for cycling Advanced cycle stop lines Cycle crossing facilities Continuity of facilities Cycle parking facility	Traffic light junctions Give-way junctions Roundabouts Vehicle volume and frequency at a junction Making a right turn at a junction Size of junction Complexity of junction Advanced stop line at a junction Number of vehicles making a turn at a junction	Safety Journey time Journey distance Comfort /pleasance Reliability

Preferences and importance for each feature were separately measured. People differently recognise importance and preference in specific matters, so respondents were asked to indicate preference and importance separately with the same features. This may cause confusion to some degree with participants, but it is important to measure them separately through the analysis of the data later; for example good scenery was highly preferred, but not a very important factor for confident cyclists. It means that scenery will be taken into account only after other more important factors are satisfied for the expectation of confident cyclists.

The thesis measured cyclists' confidence levels using various situations on roads. The variables in Table 3.8 are mainly related to traffic. It was expected that cyclists at a different confidence level would have different degrees of feeling or ability with managing such situations.

Table 3.8 Variables used to Measure Confidence Level of Cyclists

Item	Variables measured
Confidence of cyclists	Cycling with a lot of vehicles Cycling with few vehicles Cycling with high speed vehicles Cycling with low speed vehicles Cycling with HGVs or buses passing by Changing a lane in traffic Right turn with vehicles at a junction

The concept of confidence level initially came from the idea of Geller (2011). In his segments of cyclists he suggested four types of cyclists determined partially by comfort on different cycling facilities. Later, Dill and McNeil (2012) further examined Geller's work and measured level of comfort cycling on various street types for categorising cyclists.

However, the confidence level in the thesis was measured using traffic rather than cycling facilities and street types because traffic is an important factor for cyclists, having been referred to in various studies and particularly a main source of risk. So traffic volume and speed, big vehicles such as HGVs and buses, changing a lane in traffic and turning into right with vehicles at a junction were chosen as variables. Several studies found that traffic matters were important factors for cyclists, especially in terms of safety, and cyclists who were new to cycling had more fear of traffic than experts (Pooley et al. 2013; Sener et al., 2009; Winter et al. 2011). Therefore cyclists' confidence can be measured using reactions to traffic matters.

3.5.2 Structure of the Questionnaire

The questionnaire consists of 7 sections (see Appendix 1). Table 3.9 shows a summary of the information collected from each section of the questionnaire. Section 1 consists of 9 questions which ask about personal cycling behaviours and characteristics of cyclists, including cycling frequency, confidence towards traffic circumstances, etc. Most questions are single or multiple choice, except for the questions about confidence toward traffic circumstances (Q6) and motivations (Q7) which were asked to answer in 7 Likert- scales.

Table 3.9 Information Collected in the Questionnaires

Structure	Data category	Information collected
Section 1	Cyclist characteristics	Q1: Cyclist type Q2: Period of cycling Q3: Frequency of temporary stops of cycling Q4: Frequency of cycling Q5: Cycling experience Q6: Confidence level Q7: Motivations Q8: Main transport mode for daily journeys Q9: Involvement of accidents in the past
Section 2~5	Preference and attitudes	Q10~Q13: Cycling facilities Q14~Q16: Road and traffic features Q17~Q19: Intersection features Q20~Q21: Feeling unsafe
Section 6	Cycle journey	Q22: Purpose Q23: Frequency Q24: Choice criteria Q25: Safety of route
Section 7	Demographic information	Q26: City Q27: Age Q28: Gender Q29: Occupation Q30: Ethnics Q31: Education level Q32: Driving licence Q33: A number of car accessible Q34: Participating a further study Q35: Contact details

The questions from section 2 to section 5 measured the preferences and attitudes of cyclists towards cycling facilities (Q10~Q13), road and traffic features (Q14~Q16), intersections (Q17~Q19), and feeling unsafe from route features (Q20 ~Q21). All the questions were measured in 7 Likert-scales except for two: Q10 in multiple choices and Q21 in ranking.

Section 2: Attitudes to cycling facility

Q10: Experiences of using cycling facilities

Q11: Interest in using each of 9 cycling facilities

Q12: Importance of the role of a cycling facility in the view of route choice criteria

Q13: Attitudes towards continuity of cycling facility

Section 3: Attitudes to road and traffic circumstances

Q14: Preference for each of 20 features

Q15: Importance of 15 features for choosing a route

Q16: Importance of the role of road and traffic conditions in the view of route choice criteria

Section 4: Attitudes to Intersections

Q17: Agreement for 5 behaviour at an intersection

Q18: Importance of 4 intersection features for using a junction

Q19: Importance of the role of intersections in the view of route choice criteria

Section 5: Feeling unsafe from route features

Q20:Feeling unsafe from 16 circumstances

Q21: Rank of preference in 3 types of junction regarding safety

In section 6 (Q21~Q24) respondents were asked to bear in mind one cycling route which was used in frequent journeys, but not for touring or leisure trips. Respondents then answered the questions about trip purpose (Q21), frequency (Q22), reasons for using the route (Q23), and safety of the route (Q24).

Finally, section 7 (Q25~Q34) asked respondents about various demographic information as well as an indication for participation for further studies. Demographic information includes the city which they live in, age, gender, occupation, ethnic group, education level, whether or not they have a driving licence and the number of cars which they own or have access to.

The questions were basically measured in 7 Likert-scales. The Likert-scale is the most common approach to scale response in questionnaire surveys, and 5 or 7 points are also the most common. In general, there is no significant difference between 5 and 7 points; however, a 7-point scale prevents people from being too neutral in their responses slightly more (Colman et al., 1998), and 7 points will be slightly better in reliability than 5 points as scales with more points are considered more reliable. Therefore the study used 7 Likert-scales throughout the survey.

3.5.3 Data Collection Procedure

The survey was carried out both online and offline for 3 months from July 2011. A paper version of the questionnaire had been distributed on streets where cycle parking was located. However, in Leeds, the questionnaires were also distributed in university campuses because the capacity of cycle parking in the city centre was small, at around 10~20 lots. Instead, the bicycle parking in universities have a large number of lots.

The numbers of the questionnaire in the paper version distributed in Leeds were just around the half of the numbers in York. This was because there were not many places to meet cyclists in person in Leeds whereas York had many bicycle parking places with a large capacity, so it was easy to meet cyclists and to ask them to participate in the survey.

In terms of the online version, leaflets advertising the survey were distributed through local bike shops in the cities while city councils and cycling clubs were asked to send a circulating email which asked for participation in this survey. More cyclists in Leeds completed the questionnaire online, and most of them were from universities and the city council.

Table 3.10 shows the response details of the questionnaire. In total 489 sets of the questionnaire were distributed to cyclists, including 176 sets in Leeds and 313 sets in York. Among those, 59 out 176 sets in Leeds were returned while 129 out of 313 sets in York were returned. On the other side, in total 326 cyclists accessed the website but only 265 participants completed it, including 189 completions out of 214 accesses in Leeds and 76 out of 112 in York.

Table 3.10 Response Rates of the Questionnaire Survey

	Paper version			Online version			Total
	Leeds	York	Sum	Leeds	York	Sum	
Distributed *	176	313	489	-	-	-	-
Returned/Accessed	59	129	188	214	112	326	514
Completed	56	126	182	189	76	265	447

* A number of distributed questionnaires is only available for paper version.

3.5.4 Statistical Analysis of Questionnaire Data

The collected data had two different types: nominal and ordinal. At the beginning of analysis, factor analysis and cluster analysis were conducted to segment cyclists by route choice criteria and confidence level.

A normal distribution of the variables was checked before conducting statistical tests with the samples. Not all the variables obtained from the questionnaire followed a normal distribution. Small deviations from a normal distribution of each variable are acceptable; however, some variables, especially the variables related with measuring of feeling unsafe, were seriously skewed to the left. Despite transforming the variables, they still seriously violated a normal distribution, so non-parametric tests including the X^2 (chi square) test, Kruskal Wallis Test, and Mann-Whitney U test were used for the analysis.

There was often missing data which was not covered by respondents. The missing data were coded as *missing (or 99)* during data inputting into a SPSS spreadsheet. To ensure that only relevant values were considered in the analysis, this data was generally excluded from the analysis. In addition, the results of the statistical tests were only considered significant if the probability p of making the recorded observation by chance was less than either 5% ($p<0.05$) and1% ($p<0.01$).

Descriptions for more details about the statistical methods used will follow.

3.5.4.1 Factor Analysis

Factor analysis is a statistical method used to identify a small number of factors from a large number of variables. Factor analysis serves in two ways: Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA).

EFA is used to identify interrelationships among items and group items. This analysis is exploratory in nature, so researchers make no priori expectations about relationships among factors. On the other hand, CFA is used to test a theory, hypothesis or models so researchers have assumptions; for example the number of factors or which factor a theory or model fits with. In the thesis, only EFA is considered and used.

The sample size of over 300 for factor analysis is recommended in general (Comrey, 1973), which is satisfied with the samples of the thesis. At the starting point, correlation matrixes between variables were checked. Correlation coefficients '*R*' of above 0.3 are minimal. This means that if there are few correlations of above 0.3, it will be a waste of time. There are a few tests which should be conducted before conducting factor analysis: Kaiser-Meyer-Olkin(KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity. Both tests assess the suitability of the responded data for factor analysis. KMO aims to meet a value of over 0.5 between 0 and 1, and the result of Bartlett's test should be significant ($p<.05$) (Hair et al., 1995; Tabachnick and Fidell, 2007).

There are many ways determining the best fit between the variables and the latent factors which is called as factor rotation. Principal components analysis (PCA) and principal axis factoring (PAF) are the most common. In addition, PCA is most commonly used in EFA and recommended without a priori theory (Gorsuch, 1983; Thompson, 2004).

Factors are determined by several criteria. However, rather than using a single criterion, use of multiple criteria is desirable (Costello and Osborne, 2005; Hair et al., 2006; Thompson and Daniel, 1996). Kaiser's criteria (Eigenvalue) and the Scree test are common ways to determine factors, and both methods are available in SPSS.

The next step for factor analysis is to check whether a variable might relate to more than one factor using rotation. Rotation produces a more interpretable solution by maximising high item loadings and minimising low item loadings. There are several options for this step depending on whether or not we assume that factors are correlated with each other; for example Orthogonal Varimax is the most common technique with uncorrelated factors, while Oblique is the most common technique with correlated factors (Costello and Osborne, 2005).

The final step of factor analysis is interpretation, in which a researcher examines variables in each of the factor determined and gives the factor a name or theme. However, giving meaning(s) to a factor ultimately depends on the researcher's judgement (Henson and Roberts, 2006).

In this study, factor analysis is used to identify characteristics of cyclists regarding route choice criteria for choosing cycling routes and to develop cyclist types with cluster analysis.

3.5.4.2 Cluster Analysis

Cluster analysis is a method of grouping samples by similarity. Individuals in a same group share similar or close characteristics with each other, while different individuals from different groups have different characteristics. However, unlike regression and factor analysis, cluster analysis does not use a statistical method, so researchers do not need to meet any assumptions with data to conduct cluster analysis.

An important problem in cluster analysis is to decide how many clusters should be derived from the data. As a number of clusters can be decided by a researcher, final conclusions could be different and adjusted by a researcher's subjective judgement.

Deciding variables for cluster analysis is a first step. Variables used for cluster analysis need to provide different segments. Generally, using a large number of variables should be avoided as it will increase dissimilarities within the variables. A high degree of correlations among variables will lead to over-representing specific aspects amongst them. To handle this problem, factor analysis is often carried out before cluster analysis; reducing variables with similar groupings or highly correlated variables together and then generating factor scores. However, Dolnicar and Grün (2009) worried that the factor-cluster approach in the aspects of those transformed values may lead to different results, and eliminated variables with low loadings potentially can be the most important pieces of information. Despite this criticism, the factor- cluster approach may still be better if a researcher has doubts about the data structure.

There are many ways for clustering cases into groups. However, three procedures are the most common and available in SPSS: the hierarchical cluster, K-mean cluster, and two-step cluster. There are two main types of hierarchical methods: agglomerative and decisive. Agglomerative clustering is a bottom-up style. Each piece of data forms an individual cluster and these clusters are then sequentially merged according to their similarity. These works iteratively continue until one cluster forms. Decisive clustering goes in the opposite direction. All the data forms a single cluster, and then the cluster gradually splits up.

K-means cluster partitions data into k subsets. This algorithm is not based on distance measures but uses the within-cluster variation as a measure to form homogenous clusters. The clustering process starts by randomly assigning data to a number of clusters, and then the data is successively reassigned to other clusters to minimise the within-cluster variation. The within variation is the squared distance from each observation to the centre of the associated cluster.

In terms of two-step cluster, the method is a combination of the above two methods. This method firstly undertakes a procedure that is very similar to the k-means algorithm, and based on the results the method then conducts a modified hierarchical agglomerative clustering procedure. Specifically this method is designed to handle the problem of mixed variables measured on different scale. This procedure can handle categorical and continuous variables simultaneously and allows the user to specify the numbers of clusters as well as automatically have numbers chosen by statistical evaluation criteria. The procedure provides a guide for deciding how many clusters to retain from the data by calculating measures-of-fit such as Akaike's Information Criterion (AIC) or Bayes Information Criterion (BIC).

Evaluating clustering results is an important part of the analysis. Evaluation will be carried out through assessing the solution's stability and validity. Stability is assessed via testing whether or not two different clustering procedures on the same data conclude with the same results. Another approach is to split the data set into two halves and then to analyse the two subsets separately using the same parameter settings. If there is no significant difference between cluster centroids of the two solutions, the solution is adequate.

The final step of cluster analysis is the interpretation of the clusters. This work involves examining the cluster centroids, which are the average values of all data in a certain cluster. This can be checked by comparing the clusters with independent t-tests or ANOVA.

3.5.4.3 The X^2 (Chi-square) Test

The variables for the test are normal or ordinal scales. This test compares observed frequencies with expected frequencies in a contingency table and then measures homogeneity or association in normal data. The value of X^2 depends on the sample size, so the test is not suitable for measuring the strength of the association between two variables (Kinnear and Gray, 2008).

Data for each cell of a contingency table must be independent, and the minimum numbers of samples for each cell in two-by-two contingency tables is 5 in general (Clegg, 1990). For larger tables, the rate of the cells which have the expected frequency of less than 5 must be no more than 20% (Kinnear and Gray, 2008).

In the thesis, this test is used to assess whether or not there are associations between newly developed types of cyclists and confidence level, different cities or genders.

3.5.4.4 Mann-Whitney U Test

The Mann-Whitney U test is a non-parametric test to detect if there is a difference between the medians of two independent samples. This test is an alternative to the independent sample t-test in parametric tests. The test performs well with the samples with non-normal distribution (Wonnacott and Wonnacott, 1982) and can be used when the sizes of the two sample groups are unequal (Fowler et al., 1998).

The significance of the test, statistics called U depends on the sizes of the two samples. Mann-Whitney U test is used to find out whether or not there are significant differences in preferences and importance for route features by gender and city.

3.5.4.5 Kruskal Wallis Test

This test is also a non-parametric test comparing the medians of two or more independent groups of samples, and the test variable assesses individual cases on at least an ordinal scale (Green et al., 2005). The test is equivalent to ANOVA in parametric tests.

The Kruskal Wallis test ranks all groups as a whole. Any tied values are assigned to the average rank of the tied values. Then, the test statistic K is compared to the distribution of X^2. However, this does not mean that observations have to be frequencies (Fowler et al., 1998).

Degrees of freedom, *df,* are calculated by subtracting one from the total number of groups or samples as determined by the grouping variable. If the comparison with the relevant X^2 values indicates a significant difference between the medians within the whole group, it is necessary to conduct a follow-up analysis to establish which groups do differ. In the case of ordinal data, the Mann-Whitney U test is normally used.

The Kruskal Wallis test is used to find out whether or not there are significant differences in preferences and importance for route features in confidence level and cyclist types based on route choice criteria.

3.6 Phase 2: GPS Route Collection

This section presents how actual routes were collected. The GPS route collection consists of two parts. The first part is data collection and the second part is evaluation.

The data collection was carried out during the summer season in 2012 with 50 participants from Leeds and York. Each participant carried a GPS device for 5 days and then attended at an interview for a further study, which is presented in section 3.7. During the interview an evaluation of the recorded routes took place before starting the interview. This stage is designed to make a participant feel comfortable and have times for reminding their trip, as well as evaluating the recorded routes.

3.6.1 Equipment

DfT carried out a GPS feasibility study using GPS devices for improving the quality of the National Travel survey. The study identified requirements for devices for this survey (DfT, 2008b) and suggested the following criteria of requirements for GPS devices for survey purposes below:

- Form, size and weight
- Battery life
- Ease of recharging
- Memory capacity
- Cost
- Ease of use
- Ease of downloading data
- Data elements captured
- Data quality

According to the requirements above, several devices were considered and a Qstarz Travel recorder XT was selected. The device is small pocket sized and easy to carry. A battery lasts for 42 hours with a full charge, which is suitable for 5 days, and can work for 8 hours a day without recharging. Memory capacity allows for 400,000 waypoints recording. This capacity allows recording points for 13.8 days at every second for 8 hours a day. Recharging a battery is done using a USB port which is available in most computers, and also an additional adapter is provided if required. The device records date, time, latitude, longitude, heading, speed, height, etc. Bundle software allows for downloading the data into various formats, including CSV and Google Maps.

In terms of data quality, a chip set used for the device was the latest version available in the commercial market at the time of the survey. During the preliminary test period, it provided a good quality of recorded data. However, it requires 30 seconds on average and 1 minute maximum to detect satellite positions, so participants need to wait for a while after turning on a device before they start cycling.

3.6.2 Data Collection Procedure

The data collection was conducted for 16 weeks from 9th July 2012 to 26th October 2013. In total, 50 participants participated in the survey. They were asked to carry a GPS device for 5 working days whenever they cycled. The reason for doing a 5 working day survey is more practical: the initial plan was to carry out the survey for 10 weeks with 5 participants each week; however in reality, only 10 devices were prepared and it was very difficult to arrange for meetings to distribute and get the devices back. Therefore the survey was carried out for only 5 working days, and then weekends were used to get the devices back, while weekdays were usually used to distribute the devices.

The study focused on commuting and utility cycling, so only recording cycling during weekdays is reasonably acceptable, although there are chances for missing utility cycling activities during weekends.

The samples for the GPS route collection were selected from the respondents of the questionnaire. At first the study grouped the respondents by confidence level into four groups (see section 4.3.1). The respondents of each group who indicated the willingness to participate further studies were contacted by emails and letters first and a phone call later. A sampling process tried to recruit at least one sample for each of the confidence level groups. However, there was no suitable participant at the beginner level in York.

Table 3.11 shows the participants for the GPS survey and interviews. The distributions of the samples by the characteristics of cyclists were reasonably balanced except for the participants at the beginner level in York. Only one female cyclist at the beginner level in York agreed to participate in the survey. However, the number of cyclists at beginner level there was very low, so there was no other way to recruit a sample for that group.

Table 3.11 Participants for GPS Survey and Interviews

	Leeds			York			Total
	Male	Female	Total	Male	Female	Total	
Beginner	2(3)	2	4(5)	0	1	1	5
Unconfident	3	3(4)	6(7)	3	3	6	12
Confident	6(7)	3	9(10)	5	5	10	19
Very confident	3	2	5	4	2	6	11
Total	14(16)	10(11)	24(27)	12	11	23	47(50)

( ): A number of participants who completed GPS survey only

A face-to face meeting with each participant took place in advance during the previous week before a survey week. In the meeting, an instruction for using a GPS device was given to each participant. The device was returned in the following week after the survey week. The data collection lasted for 16 weeks because of difficulty arranging a schedule with 5 participants each week.

During the survey, 3 participants asked to replace a device and to conduct the survey again because they thought that the device did not work properly. However, only one case had an actual fault in the device and the other two cases had no problem with recording. However, the participants did again the survey in the following week as they had not completed the recording for 5 days.

One concern that arose regarding with the GPS survey is that participants might change their cycling behaviours during the survey; for example, they may choose a different route to reflect what they think important for cycling routes rather than what they have actually used. Participants were asked not to change their routes or behaviours such as the frequency of cycling or speed. However, this kind of bias is always possible with the collected data, although it was emphasised that taking actual and daily routes was important for the thesis.

The GPS devices recorded date, time, latitude, longitude, altitude, speed, and heading. The devices were set to record waypoints every 5 seconds to avoid failing to record whole journeys for 5 days, although the data capacity of the device seemed to be enough to record data every second for 8 hours for 5 days. This concern about the setting of recording frequency proved reasonable, as some of participants kept the device turned on until a battery completely drained off. With this setting, the data was securely recorded.

After finishing the recording and returning the device, an email was sent to arrange for an interview.

GPS data initially had noise on it for various reasons, so removing noises is an important and big task. This was carried out by manual processing. Firstly with eye detections, some completely wrong recordings were removed; for example, odd points out of Leeds or York and continuous recordings at one specific location. The former cases happened during initial acquisition time for satellites just after turning on a device, while the latter happened when a participant forgot to turn the device off after completing a trip, leaving it on overnight.

The second phase of data processing was dividing the trips into single trips and relocating odd points into a right location along the route. In many cases, returned trips were recorded continuously rather than separated into single trips, and odd points were also recorded along the routes for various reasons. These problems were also sorted out manually by hand.

Processed route data were loaded onto Google Earth to display the routes for evaluation of the routes and used for analysis.

The evaluation of the recorded routes was conducted for three reasons: Firstly reporting any faults during the survey; secondly providing further information about the recorded routes such as origin, destination and trip purposes; thirdly evaluating the quality of the routes regarding 22 circumstances which were the same variables used in the questionnaire (see Appendix 2). However, not all the recorded routes but only selected routes were evaluated. Only frequently made trips were selected and evaluated.

For the evaluation, participants were asked to give a score in 7 Likert-scales for quality regarding 5 criteria for route choice and 22 route features for each of the identified routes. The route criteria and features were same as the ones used in the questionnaire survey.

The evaluation was conducted during the interview phase.

3.6.3 Analysis of GPS Route Data

The analysis was carried out in two ways: individual case analysis and group case analysis.

In individual case analysis, two or more selected routes for individual participants were directly compared using trip data recorded by GPS and route evaluation data. This stage focused on extracting important differences among the routes; for example route choice criteria, routes features to which significantly different scores were given or trip time of a day. These differences were expected to explain why cyclists chose the route regarding the purposes of the trip.

The features and characteristics of routes and participants were then used for group case analysis to identify patterns in similarity and differences of route choice as a group. Group case analysis increases generalisability of the findings from individual case analysis, as assessing whether or not the findings make sense beyond the specific case study (Gerring, 2004; Miles et al., 2014).

The previous studies compared actual routes with computer-generated ideal routes and probed differences in proportions of road types and cycle lanes as well as traffic volumes or speeds (Menghini et al., 2010; Dill and Gliebe, 2008; Aultman-Hall et al., 1997). However, this study worked with actual routes only and compared the characteristics of the actual routes with each other.

As a preliminary step, some routes among many recorded routes were selected for analysis. Individual participants had several routes for their utility and commuting cycling. However, evaluating all the routes was not easy within the limited time (one and half hours for interviews in maximum). So the routes used for the evaluation and interviews were carefully selected to meet study aims according to the following criteria below:

1. Main commuting routes, which were used most frequently;
2. Comparable routes which share the same origin and destination for either the same purpose or different purposes.
3. Routes for other utility activities, if there are, are also selected.

3.6.3.1 Individual Case Analysis

The selected routes were categorised by trip purpose, including commuting, personal and business, as well as by directions of trips including going to work, returning and going another place. After these two processes, the routes were categorised into 4 route types including to-work, back-home, commuting and utility, though there has been some confusion about the names, especially with to-work and commuting as, in general, going to work means commuting. However, there is a light difference between them in this study.

To-work routes are a route used only for going to work or school for commuting, whereas commuting routes are a route used for both going to work and returning home from work place. Therefore commuting routes are actually a single route for round trips while a to-work route is one for one way trips, but to the workplace. Back-home routes are a route used only when returning home after finishing work or school. It should be noted that a route used for a returning trip from a place of a friend is not a back-home route. As a consequence the three route types (to-work, back-home and commuting) are all a route for commute cycling.

In terms of utility routes, all the routes used for non-commuting purposes such as personal or business trips belonged to them. The routes for personal or business purposes were relatively less selected for the route evaluation and interviews, so a number of the routes were not enough to make them a separate group. This relatively poor selection is related with the second step below.

The second step was to find variations or alternative routes for each of the selected routes. Basically the routes having alternatives or variations were given a priority to select for the evaluation and interviews. The terms of variations and alternatives are defined as follows:

> **Variations**: the routes with differences in small sections from a main route. Both the main route and variations share the same origin, destination and trip purpose. An example is presented in Figure 3.4.

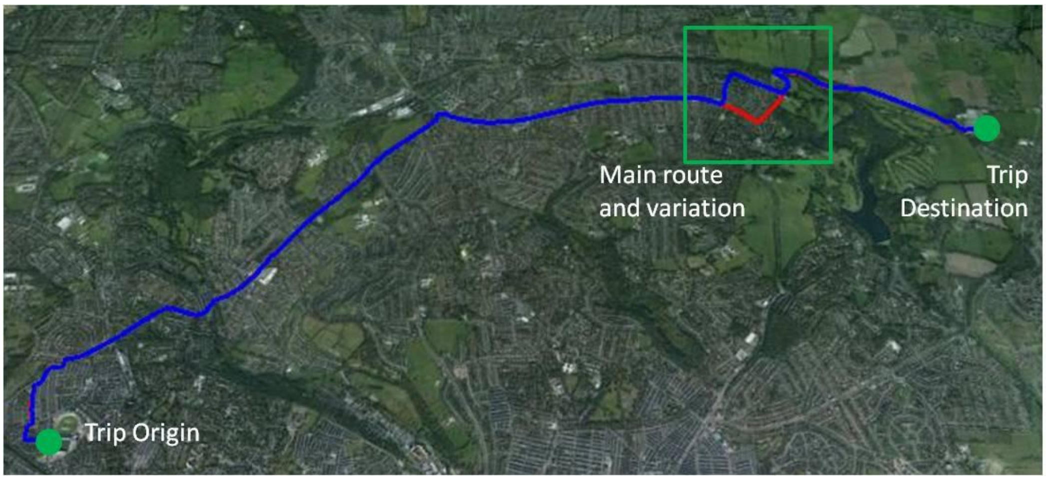

Figure 3.4 Example of a Variation of Route

Alternatives: the routes used instead of a main route. Major sections of the routes are different to each other. Both routes share the same origin, destination and trip purpose. An example is presented in Figure 3.5.

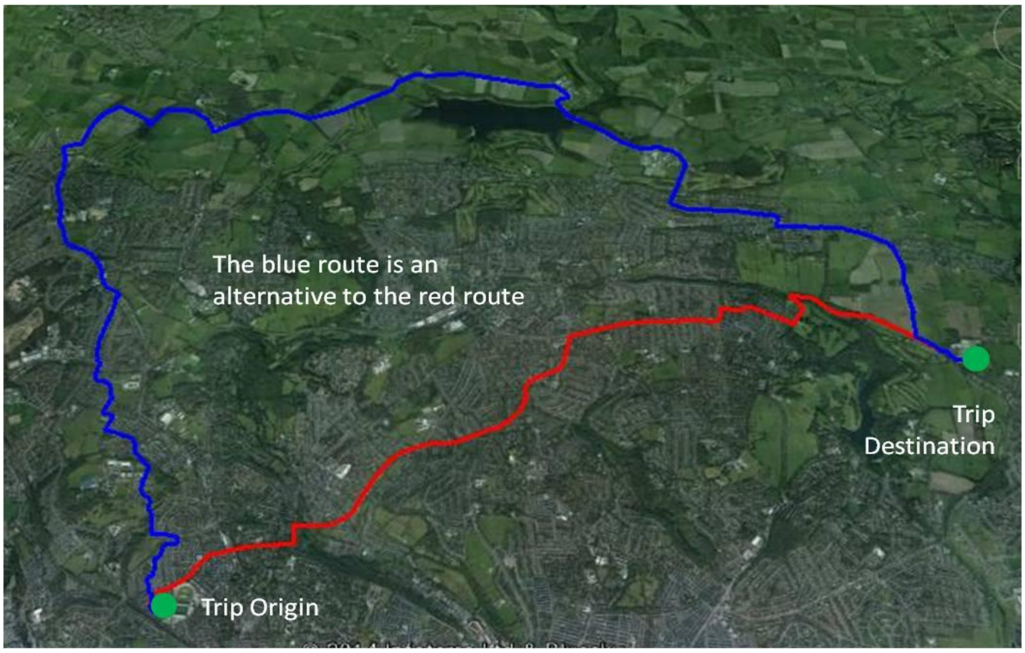

Figure 3.5 Example of Alternative Route

The third step was to do a descriptive analysis of the routes with the data of trip time, distance, evaluation for route choice criteria and quality of route features (see section 5.2 and 5.3). A comparative analysis was then carried out with to-work routes, back-home routes, commuting routes, alternatives, and variations. To-work routes were compared with back-home routes (see section 5.4.1). Alternatives and their main routes were also compared (see section 5.4.2). This step identified any important differences between a pair of the routes.

Important points in comparison analysis help to find the differences in variables between routes. For example, one of the to-work routes was 1.5km in distance, while a back-home route in a pair was 1.7km, though both routes in a pair were the same in distance. The former case obviously has a difference in distance, with a slight advantage going to the to-work route, while the latter case has no difference in distance. Like the examples, individual case analysis helps to examine differences with the characteristics of the actual routes via trip purposes. The findings in this analysis become important factors for the route choice of each participant. After this step, the analysis moves into group case analysis.

3.6.3.2 Group Case Analysis

Group case analysis focuses on probing similarities and differences in participants' current routes. Group case analysis compares the findings from individual case analysis by route choice criteria types, confidence level, city, gender and trip purposes.

Descriptive analysis for group case analysis was carried out using statistical methods such as the t-test and ANOVA tests.

3.7 Phase 3: Interviews

3.7.1 Overview of Interviews

The aim of the interview phase is mainly to find the reasons behind the choices of the routes that cyclists actually use for their cycling trips. The additional aim is to probe something new from the reasons which have been already identified or commonly believed as reasons, if there are. So interviews are exploratory as well as explanatory in nature.

The interviews were conducted in two ways. Firstly, the reasons to choose the individual routes were examined with the selected routes (which is described in section 3.6.3.1). Secondly, general preferences and reasons for the preferences about cycling route features and related matters were probed. The interviews were conducted in the form of semi-structured interviews. Various types of interviews and their strengths and weaknesses were reviewed below.

Interviews are in general categorised into three types: unstructured, semi-structured, and structured (Bernard, 1988; Crabtree and Miller, 1999; Fontana and Frey, 2005). Also, there are different categories of interviews according to techniques, for example face-to-face interviews, e-mail interviews, telephone interviews and messenger interviews (Opdenakker, 2006).

Interviews have a structure, but the level of the structure is different. Unstructured interviews are completely open-ended in a way of answering a respondent with no or little organisation (May, 1991); they simply say what they think about a given question. However, from the researcher's (interviewer's) point view, even unstructured interviews should also have a structure or plan. The researcher clearly aims to meet the purposes of the interview, so this is a great challenge for them. Unstructured interviews are useful in exploring something little known about a topic to develop ideas about it or different perspectives on a known subject (Gill et al., 2008). However, unstructured interviews are very time-consuming and it is often easy to lose direction in the interview (Gillham, 2009).

Basically semi-structured and unstructured interviews are the same in the character of answer: open-ended questions and answers. However, the key difference is that semi-structured interviews have pre-determined questions to follow during an interview. The pre-determined questions are asked to all the participants, and the participants need to answer. This way makes it easy to follow the interview process without omitting important topics which should be covered for a study (Gillham, 2009). It is the judgement of an interviewer whether or not probing further with follow-up questions for the answer of an interviewee about a specific question is worthwhile (Gillham, 2009). By this, there is a difficulty with semi-structured interviews. Semi-structured interviews need to make questions in advance, which requires pre-knowledge about the topic of a study. If there is little knowledge about the topic and it aims purely to explore the subject, unstructured interviews will be better as they will generate a lot of unexpected content. Otherwise, if the topic is already studied by someone else and the study aims to find more specific things that are as yet unrevealed, semi-structured interviews are better because they make a researcher or interviewer more focused on core topics which a researcher want to know.

In terms of structured interviews, they also have pre-determined questions to follow and often use closed questions in which a fixed set of answers are provided. An interviewer asks all the participants exactly the same questions in the same order. The interview aims mainly to collect quantitative data. Structured interviews can minimise an interviewer’s error, as little intervention is allowed during the interview, while it is not suitable to explore something less known or new because the answers are already determined by a researcher.

3.7.2 Topics questioned

The interviews were conducted in semi-structured form and face-to-face. Pre-determined questions were prepared. To find the reasons for using the selected routes, the following questions were asked to interviewees. However, the questions are not exactly same as the suggested ones and were modified during the interviews

Q1: Why do you use this route? (main route)

Q2: Is there any alternative to this one, anything better or worse than other alternatives? (In case of a route which was not recorded during the survey)

Q3: They have the same origin and destination. What is different between the main route and alternative (or variations)?

Q2 and Q3 rather overlap each other. The difference is that Q2 is asked in order to find any route not recorded but a participant occasionally uses or knows, whereas Q3 is asked when an alternative route (or variations) is recorded and it allows direct comparing with the main route.

The second part of the interview aims to explore what opinions interviewees have for route features or route environments which influence the choice of cyclists. The features were identified through the questionnaire survey. Table 3.12 shows the themes and questions involved. The core questions were asked to all the interviewees while the optional questions were asked only when such topics appeared during the interview.

The questions for the interviews were not fixed but usually followed the suggested ones. Moreover the orders of the questions were also not fixed. However, when relevant words to each of the questions were mentioned the relevant question was asked. Otherwise the questions were asked individually in the middle of talking or at the end of the interview.

Table 3.12 Themes and Questions for the Second Part of the Interviews

Themes	Interview questions		Core/ Option
Demands for improvement of cycling routes	Q4.	What do you expect from the local council or national government to improve cycling routes?	C
Influence of cycling facilities	Q5.	Do you think cycling facilities actually influence your route choice?	C
Recommended routes	Q6.	Do you think recommended routes by the council are useful for your cycling journeys?	C
Drivers' attitudes	Q7.	What do think about drivers' attitudes to cycling or cyclists in the city?	C
Junction types	Q8.	Which junction type and why do you prefer among roundabouts, signalised, and give-ways junctions?	C
Dismount at junction	Q9-1.	Do you dismount at a junction? If yes, why do you dismount?	C
Advanced cycle stop line	Q9-2.	What do you think about advanced cycle stop lines at a junction? Is that useful?	C
Cycling path types	Q10.	Which type of cycling facilities and why do you prefer among cycle lanes, segregated?	C
Shared bus lanes	Q11.	What do you think about the bus lanes shared with bicycle?	C
Differences from other cities	Q12.	Is there any difference for cycling in the city and any other cities where you have cycled?	O
How to find a route	Q13.	How did you find your route(s)?	O
Traffic volume or speed	Q14.	Which one and why is more important for you between traffic volume and speed?	O

3.7.2 Interview Procedure

The interview phase was planned for 23rd October 2012; however, the phase was carried out over 10 weeks from 26th November 2012 to 1st February 2013 due to personal matters.

In total 47 out of 50 participants who completed the GPS phase took part in the interview. The meetings were held in a room in the department (ITS) for the participants in Leeds and a café for the participants in York. A voice recorder was used to record these interviews. Before starting, each participant was asked to read and sign a consent form (see Appendix 3). After finishing an interview, an incentive of £15 in cash was provided and a signature for receiving this incentive was taken. The interview lasted between 1 hour and 1.5 hours depending on the number of the routes recorded and amount of discussion about those.

The routes, after being pre-uploaded on Google Earth, were displayed to a participant. Showing the routes to an interviewee made their thoughts more realistic because it helped them to check their routes whenever they needed to and reminded them of the features and experiences along the routes.

The questions were asked for the selected routes one by one. Q1~3 were asked for all the selected routes, while Q4~14 were asked in the middle of an interviewee when a relevant theme appeared with the route or at the end of the interview.

3.7.3 Analysis of Interview Data

The analysis process for interview data is same as the one for GPS route analysis. It also analyses the data on an individual level before then moving onto the group level. However, in qualitative analysis, individual case analysis is called *within-case* analysis while group analysis is called *cross-case* analysis.

The first step in within analysis is transcribing and coding data. Transcribing and coding are steps for identifying concepts, themes and events from what interviewees said. Researchers then compare concepts and themes or combine separated events to seek to answers for the questions they made (Rubin and Rubin, 2005). Finally, researchers can draw theoretical conclusions with developing relationships among identified codes and themes.

3.7.3.1 Transcribing Data

In total 47 audio recordings were personally transcribed into MS Word documents. While transcribing the interviews, the author made himself familiar with the data and developed some themes or concepts for the analysis. Transcribing is a time consuming process, so although it was stated that all the sayings from the interviewees were included in the transcriptions, some of the sayings which were not relevant to the study were excluded. However, non-word-based expressions such as stresses, overlaps and laughing were included because it helped to understand doubts or emphasis on the meanings.

3.7.3.2 Coding Process

The transcripts needed to be organised to give meanings to each of the chunks of words for further analysis. This step is known as coding, which is defined as ‘most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing and/or evocative attribute for a portion of language based or visual data’ (Saldana, 2013; p.3). Coding is also the work to connect data collection and the explanation of the meanings of the data (Charmaz, 2001)

The coding was carried out based on the hybrid approach of using the responsive interviewing formal coding scheme and the grounded theory together. In the responsive interviewing formal coding scheme, researchers prepared ideas on themes or concepts from the literature or developed new themes if appropriate before doing physical coding (Rubin and Rubin, 2005).

On the other side, in the grounded theory coding, recognising concepts and themes and developing theory are a single integrated process. The concepts and themes must be developed from coding every single passage without pre-identified ideas (Corbin and Strauss, 2008).

Rubin and Rubin (2005) pointed out how the hybrid way is more efficient when researchers focus on the interviews because they can select only those concepts or themes most closely related to the research questions without coding every single passage.

Coding started with dividing the transcripts of each case into relevant themes, which were based on the interview questions. The relevant themes are priori codes. The quantitative part of the study already provided the useful themes and concepts for cyclists’ route choice matters.

Table 3.13 shows pre-defined themes/concepts and codes used for the coding. The pre-defined themes/concepts were taken from the questions in interviews while the pre-defined codes were taken from the items used in the evaluation process for GPS routes and the questionnaires.

Table 3.13 Priori Themes/Concepts and Codes

Pre-defined Concepts/Themes	Pre-defined codes
Reason for using a route	Short- distance
Advantage of a route	Short- time
Disadvantage of a route	Safe
Expectations for route improvement	Reliable
Recommended cycling network by council	Pleasant
Driver's attitudes	comfortable
Influence of cycling facilities	Traffic volumes
Influence of Advanced stop lines	Traffic speed
Preference of Junction types	Lane width
Usefulness of shared bus lanes	Buses
Traffic Volume Vs. Traffic Speed	HGVs
	Cycling facilities
	Vehicles parked on street
	Main roads
	Residential roads
	Roundabouts
	Signalised junctions
	Give-way junctions
	Rights turns
	Left turns
	Uphill
	Surface
	Scenery
	Personal security
	Lightings (in darkness)

However, more codes and themes were also identified through the coding process. These kinds of themes/concepts and codes are called inductive codes. The meaning of what participants said was often slightly different from one of the pre-defined codes or themes or was a completely new idea. For example, some participants mentioned the one-way system in the road network, and the one-way system forced them to use a different route or partially a different section. These inductive themes/concepts and codes are summarised in Table 3.14.

Table 3.14 Inductive Themes/Concepts and Codes

New themes/concepts	New codes
Alternative	One-way system
Variation	Direct
Greens	Convenient
Riverside	Pay-off
	Always
	Depend
	Icy
	Weave in and out
	Recognition
	Knowing traffic light sequence
	Sandwich
	Get used
	Logical way

The coding was continuous reading and re-reading the transcripts. All the transcripts were stored in MS excel, and the relevant code(s) were directly noted next to each paragraph or passage on the right side, while on the left side of a paragraph the relevant theme was noted. Table 3.15 shows an example of this process.

Table 3.15 Example of Coding Process

Theme	Paragraph	Code1	Code2
Reason to use	I think I use that route because it seems the most convenient… I mean, I think it's probably the shortest route. Maybe not (in distance)	Convenient	Short-time

The next step in the coding process was to merge similar codes and themes. After re-examining the codes identified through the coding process, all the passages of each interviewee with similar codes were sorted out and their descriptions compared. If the descriptions from the different interviewees under a similar code were same, the two or more codes were merged into one and the name was selected to best represent the character of the codes. After finishing merging the codes, the exactly same ways were applied for merging the themes. This work generated new themes from the related themes. The new emerged themes provided the groundwork for cross-case analysis by surfacing common themes and became the key findings in section 6.2.

3.7.3.3 Cross-case Analysis

The purpose of cross-case analysis is to deepen our understanding and explanation through examining similarities and differences across cases (Miles et al., 2014). The mixed strategies of case-oriented and variable-oriented approaches were used in the thesis. A case-oriented approach proposed by Ragin (1987) examines the case as a whole entity. The approach looks at configurations, association, causes and effects within the case and then compares a number of cases looking for similarities, associations and different outcomes for a more general explanation (Miles et al., 2014). On the other side, a variable-oriented approach looks for themes across the cases. The approach examines variables and their interrelationships rather than cases and focuses on finding the broad patterns across them (Miles et al., 2014).

The study firstly looked at a series of the cases using a somewhat standard set of variables (merged themes) and analysed each case in depth looking for relationships among the themes and codes. It then moved on to comparing the cases for general explanations, showing how the similar themes produced the same or different outcomes in the groups of cases.

3.8 Research Ethics

The study involves human participants as samples. With this in mind, there are several issues which should be considered. Before conducting the questionnaire phase, the university ethical reviews were completed and the plan was approved by the panel of AREA Faculty Research Ethics Committee, University of Leeds (AREA 10-614).

There are four core issues for the thesis regarding research ethics below:

Issue 1: Agreement of participants and providing enough information about how thee collected data is managed

Issue 2: The right to withdraw from the study at any time they want without giving reasons.

Issue 3: Keeping secret information related to the privacy of participants and personal information

Issue 4: Potential benefits and disadvantages of participants in the study

The questionnaire provided the purposes of the study on the front page and only cyclists who wanted to respond to the survey could do so without revealing the core personal information of name, contact details and address. However, if respondents wanted to participate in further studies, they needed to provide such information. For that case, the right of withdrawing from the study at any time without giving reasons was given to the participants. For the interviews, a formal content form had to be filled in before starting the process (see Appendix 3). The consent form again contained the right to withdraw.

The data was kept in a secured data storage unit which required a password to gain access. The password was not revealed to anyone else except for the only researcher of this study.

All the analysis results of the questionnaire part were presented anonymously. The analysis results of the GPS data and interviews were often presented with limited information about the participants, such as age range, city to live in, gender and cyclists types, but it was not possible to recognise who they were with such information.

Another potential matter was the routes which the participant might not want to provide or reveal. There was no such case during the study. However, even in that case, the routes could be deleted in front of the participant if required.

There were no direct benefits and disadvantages to participating in the data collection. However, the participants in the interviews were provided with an incentive of £15 as compensation for their time..

During the actual data collection work, there was no issue related to ethics.

3.9 Limitations of the Methods

The data collection process had a number of limitations, especially in the questionnaire stage. The sample had a few biases. Restriction of available funds limited the available options for the questionnaire survey. Many of the respondents to the questionnaire in Leeds were university/city council employees or students, as recruiting was attempted through a circulated email in universities and the city council, heavily relying on the on-line survey. In addition, the places where the questionnaire was distributed were also university campuses or nearby areas which are located in the northern area in Leeds. This caused most of the respondents in Leeds to be from the northern area, failing to represent cyclists who live in the south. In York, although the situation was better than in Leeds, the questionnaire was distributed in several points in the city centre, so only the cyclists who accessed that area were recruited.

Another limitation was the concept of confidence level in cyclists. The initial idea was that self-indicated experience levels and measured confidence to traffic circumstances together could represent the cycling ability of individual cyclists on the road. However, the self-indicated experienced failed to segment the respondents as many of them thought of themselves as experienced cyclists or very experienced. This result may also be linked to the sampling problem again. The study could not recruit more cyclists in the early stage of cycling. For more clear segmentation of the cyclist types, cyclists with various periods of cycling should have been recruited. However, not many respondents were new cyclists or cyclists who had cycled for a relatively short period.

Another issue was lack of time for the interviews. The interviews attempted to collect too much information in just 1.5 hours, so the data from the process was rather descriptive and did not go deeper inside the topics mentioned. Often the interviewer needed to hurry to make an interviewee finish what they were saying. So the study rather missed a chance to reveal more opinions about cycling route choices from the interviews.

Chapter 4 Questionnaire Analysis

4.1 Introduction

This chapter presents findings from the analysis of the questionnaire survey. It addresses the questions 1 to 5 in the phase 1 of the study (see Table 3.2), and the emphasis through the chapter is the development of cyclists types and probing differences in preference and attitudes of cyclists regarding route choice contexts.

Section 4.2 presents characteristics of respondents, including demographical information and descriptive analysis of cycling behaviours of respondents such as trip purposes. Section 4.3 presents developments of cyclist typologies, firstly by confidence levels and secondly by route choice criteria. Section 4.4 highlights the overall attitudes of respondents towards various factors of cycling routes. This section includes preference and priority about route factors, agreement for behaviours and the degree of feeling unsafe from route factors. From section 4.5 to 4.8 we show the difference in the attitudes of respondents by selected characteristics including gender, city, confidence and priority in route choice criteria in order. These sections focus on presenting the differences by the variables. Finally, conclusions are presented in section 4.9.

4.2 Characteristics of Respondents

This section presents characteristics of samples of the study.

4.2.1 Demographic Information of Respondents

The study collected 7 pieces of demographic data in respondents, including age, gender, occupation, ethic, education level, having a driving licence and car ownership (Table 4.1). The results of descriptive analysis were compared with the 2011 census data, except for occupations and having a driving licence. The comparison results showed that the samples fairly well represented the commuter cyclists in Leeds and York except for in terms of education levels.

However, it should be noted that the census data is only for commuter cycling without utility cycling such as shopping. So the samples for the study

Table 4.1 Summary of Demographic Information of Respondents

Unit: %

	Total	**Leeds (N=245)**	**York (N=202)**
Gender			
Male	60.6	69.4(82.3)	50.0(58.9)
Age			
18-24	14.5	14.3(16.1)	14.8(15.3)
25-34	24.4	24.9(31.2)	23.8(22.2)
35-44	22.1	24.5(26.4)	19.3(25.2)
45-54	28.2	28.2(18.8)	28.2(24.0)
55-64	9.6	8.1(6.5)	11.4(11.5)
Over 65	1.1	0.0(0.9)	2.5(1.9)
Employment status			
Employed	74.7	79.6	68.8
Students	17.7	17.6	17.8
Others	7.6	2.8	13.4
Ethnics*			
White British	85.7	86.5(85.1)	84.7(90.1)
White other	10.7	9.4(7.6)	12.4(6.0)
Others	3.4	4.1(7.3)	2.6(3.9)
Education†			
GCSEs or less	5.1	2.9(37.8)	7.9(43.5)
A-level/BTEC	13.0	10.2(13.7)	16.4(15.1)
Degree or higher	81.7	86.9(48.5)	75.2(41.3)
Having driving licence			
Yes	86.6	87.3	85.6
Car owned or accessible			
None	26.6	24.1(28.2)	29.7(22.6)
One	55.5	58.8(47.3)	51.5(52.4)
2+	17.9	17.1(24.5)	18.8(25.0)

(Number): Census 2011 data (Nomis, 2014)
*1 male respondent in York refused to indicate his ethnic
†1 female respondent in York refused to indicate her education level

and for the census data are not exactly the same as each other. However, they are quite similar and comparable with each other, as 87.9% of the samples of the study indicated that they were commuter cyclists. So the census data is a good guide for checking the validity of the representability of the study samples.

The key difference between Leeds and York in the characteristics of respondents was that more females cycled in York than in Leeds. This difference was similar to the proportions of males and females who cycled to work in York and Leeds in the census data (Nomis, 2014).

More details about the samples followed below in turn.

4.2.1.1 Gender

Overall 61% of respondents were male cyclists. However, there was a large difference in the rates of male and female respondents between York and Leeds. Only 30.6% of the respondents in Leeds were female while a half of the respondents in York were of that gender. Significantly more female cyclists were recruited from York.

According to 2011 census data (Nomis, 2014), there were 6,210 people who cycled to work in Leeds while 11,087 people did so in York. Among them, 17.7% were females in Leeds while 41.1% were females in York. The proportion of the female respondents of the study in York was very similar to the proportion of the samples of the census data, while the females of the study respondents in Leeds were rather over-recruited and so might be over-represented.

4.2.1.2 Age

Most of the respondents were recruited from three age groups: 25~34, 35~44 and 45~55. There was a slightly larger rate of responses in the group of 45~54 (28.2%) than the other two groups of 24~35 (24.4%) and 34~45 (22.1%). Whereas the group of 18~24 had just about a half of the rates of the three groups. The rate of responses from the age group of over 55 years old was quite low. The group of 55~64 was 9.6% while the group of over 65 was only 1.1% with even no response at all in Leeds. There was no significant difference in the distributions of age between the two cities. However, slightly more responses from younger groups were collected in Leeds while more responses from older groups in York.

The proportions of the samples by age both in Leeds and York were similar to the proportions of the census data. However, there were also slight differences with a few age groups. In Leeds, the group of 25-34 was rather under-represented while the group of 45-54 was over-represented. Whereas, In York, the group of 35-44 was under-represented while the group of 45-54 was over-represented. So the group of 45-54 tended to be over-represented in the samples regardless of the cities.

4.2.1.3 Employment Status

Seven different employment statuses were collected including Working as an Employee, Self-employed With Employees, Self-employed Without Employees or Freelancer, Retired, Looking After Home or Family, Unemployed and Student. However, only Working as an Employee and Student had significant proportions. So the three categories of Working as an Employee, Self-employed With Employees and Self-employed Without employees or Freelancer were merged into the category of Employed. On the other side, Retired, Looking After Home or Family and Unemployed were merged into the category of Others, which are mostly similar to being unemployed.

74.7% of respondents were employed and followed by a student status with 17.7%. There were slight differences in the proportions of employment statuses between Leeds and York. Slightly more respondents in York (13.4%) belonged to Others than in Leeds (2.8%).

There is no comparable data in the census. The census data provides commuter cycling only so Students or Others are not included in the cycling data of the census.

4.2.1.4 Ethnics

In total, 85.7% of respondents indicated themselves as White British and 10.7% of respondents as White Other. Only 3.4% of them were non-white cyclists. There was no significant difference in the distributions between Leeds and York.

When comparing the results with the census data, White Others were rather over-recruited both in Leeds and York while Others were under-recruited. However, the samples were acceptable and could be considered to represent the population in Leeds and York because the proportions of White British groups were similar to the proportions of the census and this study does not intend to study cycling route choices of the minority groups.

4.2.1.5 Highest Education Levels

81.7% of respondents completed a first degree or higher education, 13% of them did A-level or BTEC and 5.1% undertook GCSE or less. Although there was not much difference in cities, slightly more respondents in York belonged to the groups of either GCSE or less or A-level/BTEC and less in the group of Degree or Higher.

However, when comparing the results with the census data, the samples of the study were extremely biased in recruiting almost twice as many samples from the group of Degree or Higher than the expected sizes of samples from the census. In the census, the samples at Degree or Higher (Level 4 qualification and above) were only 48.5% and 41.3% for Leeds and York respectively, whereas the proportions of the responses for the study were 86.9% and 75.2% for Leeds and York respectively. The GCSEs or Less group was under-recruited for the study. Although over-recruiting samples from highly educated people is quite usual in cycling studies, obviously these samples can hardly represent cycling route choices by education levels.

4.2.1.6 Driving Licence and A Number of Cars Owned or Accessible

Of the respondents 86.6% had driving licences, and there was no significant difference in the proportions of having a licence between Leeds and York.

In terms of the number of cars owned or accessible, 73.4% of respondents overall had at least one car in this category. However, slightly more respondents in York had no car, though there was no statistical significance with the proportions between Leeds and York.

In comparison between the study samples and the census data, respondents in Leeds were under-recruited for the categories of None and 2+ and over-recruited for the category of One whereas respondents in York were under-recruited for the categories of One and 2+ and over-recruited for the category of None. Despite this, the samples fairly well represented the car ownership of the cyclists of both cities.

4.2.2 Cycling Behaviours

Cycling behaviours of respondents were analysed. The measured behaviours includes trip purposes, periods of having cycled, frequency of cycling over the last month, self-indicated cycling experience and experience of having an accident in the past. Table 4.2 shows a summary of the cycling behaviours of respondents.

Table 4.2 Summary of Cycling Behaviours of Respondents

Unit: %

	Total	Leeds (N=245)	York (N=202)
Trip purpose			
Commuting only	15.2	18.4	11.4
Utility only	2.5	0.8	4.5
Commuting +Utility	16.3	13.1	20.3
Commuting +Leisure/Touring	20.8	28.6	11.4
Utility +Leisure/Touring	5.1	2.0	8.9
Commuting +Utility +Leisure/Touring	35.6	31.8	40.1
Other†	4.5	5.3	3.4
Period of cycling			
Under 1 year	4.3	4.5	4.0
1-3 years	10.1	10.6	9.4
Over 3 years	85.7	84.9	86.6
Self-indicated experience			
New to cycling	0.2	0.4	0.0
Inexperienced	0.7	0.8	0.4
Starting again and inexperienced	4.5	4.5	4.5
Starting again but experienced	3.8	3.3	4.5
Somewhat experienced	14.1	15.1	12.9
Fairly experienced	28.4	32.7	23.3
Frequency of cycling			
5+ per week	60.2	55.5	65.8
At least 1 per week	30.6	33.1	27.7
1-3 per month or less	9.2	11.4	6.5
Experience of accidents			
None	12.3	11.4	13.4
Near miss	36.7	33.5	40.6
Slight accident without medical treatment	28.9	31.8	25.2
Slight accident with medical treatment	15.4	16.3	14.4
Serious accident	6.7	6.9	6.4

† This includes leisure/touring only cyclists and cyclists who did not indicate any cyclist types related with trip purposes

Most of respondents cycled for multiple purposes: commuting, utility and leisure/touring. Significantly more respondents in York cycled for utility purposes than in Leeds. A higher rate for utility cycling in York indicates that cycling in York is a more ordinary activity than in Leeds.

Most of the respondents had also cycled for more than 3 years. Furthermore, when the responses of having cycled for the periods of 1-3 years were included, the percentage increased to 95.8%. These findings were related with the findings from self-indicated experience levels. Most of the respondents thought that they were experienced cyclists (94.6%). These two findings together

may indicate that 1 year will be a critical period which makes cycling activity of new comers settle down and stable. On the other hand, the small percentages of inexperienced cyclists and cyclists who had cycled for less than 1 year may mean that relatively small numbers of new cyclists had joined for commuting or utility purposes.

In terms of frequency of cycling, 90.8% of respondents cycled once every week. Existing cyclists quite frequently cycled for commuting and utility.

The majority of respondents had experiences of accidents or near-missed opportunities, with only about 12% of respondents not having such experiences. These results clearly indicate that cyclists are frequently exposed to the danger of being injured during cycling, and this is why safety is a key barrier to encouraging cycling.

There were few differences found in the cycling behaviours between Leeds and York. However, the respondents in York more cycled for utility purposes and more frequently, had less experience with slight accidents and little to no experience of having substantial accidents. So marginally, as the differences were not significant in statistical terms, the cyclists in York were more active in cycling and had a safer environment.

4.2.2.1 Trip Purposes

Respondents were asked to choose cyclist types to describe themselves in multiple choices regarding trip purposes. The types include commuter cyclists, utility cyclists and leisure/touring cyclists.

The results indicated that most of respondents cycled for multiple purposes. 77.8% of respondents cycled for at least two purposes among commuting, utility and leisure/touring, while only 17.7% of respondents cycled for a single purposes (either commuting or utility).

In detail, 87.9% of respondents cycled for commuting while only 59.5% did so for utility, so commuting was a more important reason for cycling as transport means. We can also see that 61.5% of respondents cycled for leisure/touring as well, while only 34% of respondents cycled purely for transport.

An important difference between Leeds and York in trip purposes was that respondents in the latter more cycled for utility purpose than in the former; almost double percentages of respondents in York indicated that they cycled for utility, with 64.9% in York and 34.6% in Leeds. It indicates that cycling in York is common in more various daily activities.

4.2.2.2 Period of Having Cycled

Of our respondents, 85.7% indicated that they had cycled for more than 3 years while 10.1% had cycled for over 1 year but less than 3 years. So only 4.3% of respondents had cycled for less than 1 year.

There was no significant difference in the period of cycling between Leeds and York. These results may indicate that starting cycling for commuting or utility purposes has not been easy and cycling is still a transport means for existing users.

The 2011 census data (ONS, 2014a) revealed that the number of people cycling to work in Leeds increased by 48.9% (from 4,189 persons to 6,237 persons) since 2001, while in York the numbers increased by 7.5% (from 10,508 to 11,297). Although the increase in Leeds seems significant, it is over a period of 10 years, whereas there was only an increase of 789 persons for 10 years in York. Therefore it could be systemically difficult to find cyclists who cycled for less than 1 year for commuting or utility purposes. In addition, this also indirectly indicates that encouraging cycling in England was not very effective over the last 10 years. This statement was supported, by the decrease in cycling to work in the majority of local authorities in England despite the large increases in London and several local authorities (ONS, 2014b).

4.2.2.3 Self-Indicated Cycling Experience

Experience levels were categorised into 7 levels: *New to Cycling, Inexperienced, Starting Again and Inexperienced, Starting Again but Experienced, Somewhat experienced, Fairly Experienced* and *Very Experienced.*

About a half of respondents thought they were *Very Experienced* cyclists (48.3%), while 28.4% of them believed themselves to be *Fairly Experienced* cyclists and 14.1% stood at *Somewhat Experienced*. So overall 94.6% of respondents thought they were *Experienced* cyclists (including 3.8% in the group of *Starting but Experienced*). Although more respondents in York indicated that they thought of themselves as *Very Experienced* than in Leeds, there was not much difference in the experience levels between Leeds and York.

The results are related with the results of section 4.2.2.2 (Period of having cycled.) Both results show similar tends; most of the respondents had cycled more than 1 year (95.8%) and thought themselves as experienced cyclists (94.6%). This indicates that cyclists think that around 1 year is the period that they get experience for cycling. Keeping new cyclists cycling for around 1 year will make their activity settle down and stabilise.

4.2.2.4 Frequency of Cycling

The majority of respondents (60.2%) cycled more than 5 times per week while another 30.6% cycled at least once a week. Overall, 90.8% of respondents cycled once every week. This indicates that cycling is a usual activity of the daily life for existing cyclists.

There was a slight difference between Leeds and York. Respondents in York cycled slightly more frequently than respondents in Leeds: 65.8% for 5+ per week in York and 55.5% in Leeds.

4.2.2.5 Experience of Accident in the Past

We then examined any serious accident respondents had experienced during cycling in the past, finding that 51.0% of respondents had experience of having accidents while 49.0% did not. However, 36.7% of respondents said that they had the experience of having dangerous moments (near-misses). Only 12.3% of respondents completely did not have any experience regarding accidents.

It is interesting that 87.7% of respondents had experience of having accidents or near-misses. This high rate may correspond with the continuous increase in the proportion of reports of accidents involving cyclists from 6.4% in 2005 to 10.5% in 2012 in West Yorkshire (Lovelace et al., forthcoming). This result indicates that exposure to danger is usual for cyclists and can explain why safety is always a barrier when starting cycling (Pooley et al, 2011b; Fisherman et al., 2012; Reynolds et al., 2009; Lorenc et al., 2008; Davies, 2014). Not only non-cyclists but also existing cyclists are always in great danger during the activity.

4.3 Segmentations of Cyclists

As proposed in the literature review (see section 2.6), the study used confidence levels and route choice criteria to develop segmentations of cyclists for route choice.

This section presents how the segmentations were produced and what characteristics the developed types of cyclists had.

4.3.1 Segmentation by Confidence Level

The questionnaire was designed to obtain information about the self-indicated experience and confidence levels of respondents in various riding circumstances on roads. However, it was not rational to use the self-indicated experience to classify cyclists, as most of respondents indicated that they were experienced cyclists to varying degrees (see Table 4.2). On the other side, confidence in riding circumstances had relatively good distributions through given scores, so only confidence level was used for the segmentation process.

In order to measure confidence level of respondents on roads, seven riding circumstances (see Q6 in Appendix 1) were used including large traffic volume, small traffic volume, high traffic speed, low traffic speed, HGVs or buses passing by, changing a lane in traffic, and right turn with vehicles at a junction. Table 4.3 shows a summary of descriptive analysis of the data.

Table 4.3 Descriptive analysis for Confidence to Traffic Circumstances

Variable	Mean	Std.Dev	Skewness	Kurtosis
Large traffic	4.83	1.578	-.586	-.529
Few traffic	6.36	1.167	-2.768	8.623
High traffic speed	3.81	1.734	-.012	-.983
Low traffic speed	5.76	1.316	-1.309	1.712
HGVs or buses	3.72	1.748	.060	-1.063
Changing a lane in traffic	4.34	1.683	-.297	-.773
Right turn at junction	4.57	1.607	-.435	-.554

Among the 7 variables, 2 were excluded: few traffic volume and low traffic speed. The means of the two variables were 6.36 and 5.76 respectively. The means were too skewed to the maximum score of 7 so the variables did not work as discriminative variables for the purpose of segmentation of cyclists.

Another reason that the two variables were excluded was that using only 5 variables was easier than using 7 variables to set a proper range of an index, which was developed for measuring the confidence level of individual respondents. The index was an average of the scores of the selected 5 variables. Figure 4.1 shows the frequency distribution of this index. The index follows a relatively good normal distribution.

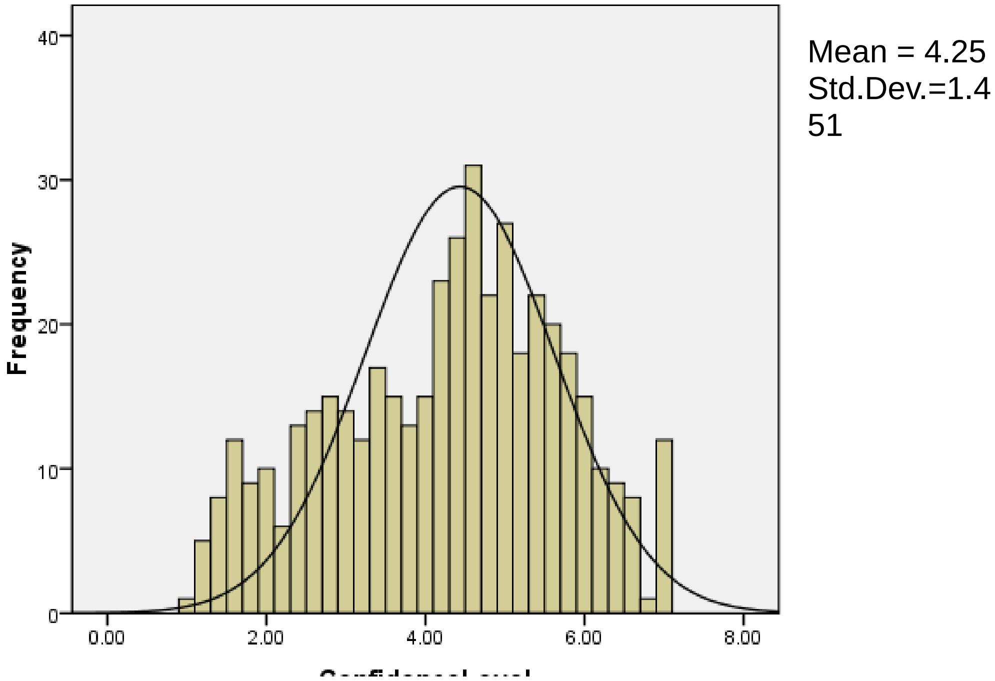

Figure 4.1 Histogram of Index of Confidence Level with a Normal Curve

Four groups were defined by confidence level, and split under the titles of *Beginner, Unconfident, Confident* and *Very Confident*. The intervals of the index score for each group were equally divided. Table 4.4 shows the statistical results of the Confidence Level Index (CLI).

Table 4.4 Statistics of Confidence Level Index

Level	Mean	Range	Proportion(%)
Beginner	1.84	X < 2.5	14.5
Unconfident	3.20	2.5=< X <4.0	22.7
Confident	4.71	4.0=< X <5.5	41.7
Very confident	6.12	X >= 5.5	21.1

The largest proportion of respondents belonged to *Confident* with 41.7% followed by *Unconfident* with 22.7%. About 15% of respondent were grouped into *Beginner* while 21.1% of them were in *Very Confident*. Overall 62.3% of respondents were identified as cyclists who were confident or more at cycling with rather difficult circumstances on roads.

4.3.2 Segmentation by Route Choice Criteria

The literature review presented a few studies which used a factor-cluster analysis for segmenting cyclists to probe their characteristics. The study also developed segments of cyclists using a factor-cluster analysis based on route choice criteria which affects the judgement of route selections.

Five criteria were measured, including *Safety, Time, Distance, Comfort/ Pleasant* and *Reliability*. All the criteria were derived from previous studies (Van Shagen, 1990; Westerdijk, 1990: Dill and Gliebe, 2008) except for reliability. Reliability is mainly related with trip time, but also with any expected or unexpected obstacles, such as congestion. It is also related with variability and uncertainty in the journey (Carrison et al., 2012). So reliability was included to measure the variability and uncertainty of routes for cycling trips.

4.3.2.1 Variables used

The questions Q12, Q14, and Q18 were used to identify what criteria respondents importantly take into account for route choice. The study separately measured the importance of each criteria in respect to road and traffic features, cycling facilities and intersections along routes rather than simply asking importance of each criterion for route choices. The data collection produced 15 different variables: importance of 5 criteria for 3 categories. The variables measured are listed in Table 4.5.

Table 4.5 Measured Variables and Abbreviations

Variable	Abbreviation
How important do you think cycling facilities are for saving journey times?	Time-Facility
How important do you think cycling facilities are for minimising journey distance?	Distance-Facility
How important do you think road and traffic circumstances are for saving journey times?	Time-Traffic
How important do you think road and traffic circumstances are for minimising journey distance?	Distance-Traffic
How important do you think cycling facilities are for a reliable journey?	Reliability-Facility
How important do you think road and traffic circumstances are for a reliable journey?	Reliability-Traffic
How important do you think cycling facilities are for the safety of cycling routes?	Safety-Facility
How important do you think road and traffic circumstances are for the safety of cycling routes?	Safety-Traffic
How important do you think intersections are for the safety of cycling routes?	Safety-Intersection
How important do you think intersections are for saving journey times?	Time-Intersection
How important do you think intersections are for minimising journey distance?	Distance-Intersection
How important do you think intersections are for a reliable journey?	Reliability-Intersection
How important do you think intersections are for comfortable or pleasant riding?	Comfort-Intersection
How important do you think road and traffic circumstances are for comfortable/pleasant riding?	Comfort-Traffic
How important do you think cycling facilities are for comfortable/pleasant riding?	Comfort-Facility

4.3.2.2 Factor Analysis

A factor analysis with variables was carried out using Principal Component Analysis for the extraction method and Oblimin for the rotation one, which is used for correlated factors. Scree plot and Eigenvalues larger than 1 were used to extract factors. All items with a factor loading greater than 0.3 were included in the factors because any value over ±0.3 is considered to make a significant contribution to a factor (Field, 2005). In terms of cross-loaded items, meaning items with a factor load of over 0.3 appear on two or more factors, they were included to a factor where the item had a higher factor loading value.

The analysis produced 4 sets of factors: *Quick, Safety*, *Intersection* and *Comfort*. Table 4.6 shows the summarised results of this process.

Table 4.6 Factor Analysis for Importance of Route Choice Criteria

Variable	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**
	Quick	*Safety*	*Intersection*	*Comfort*
Time-Facility	**.821**	.192	-.294	.120
Distance-Facility	**.816**	.162	-.256	.076
Time-Traffic	**.789**	-.011	-.380	.028
Distance-Traffic	**.772**	-.006	-.335	-.037
Reliability-Facility	**.664**	.612	-.250	-.065
Reliability-Traffic	**.620**	.496	-.381	-.153
Safety-Facility	.072	**.733**	-.081	.451
Safety-Traffic	-.141	**.699**	-.108	.503
Safety-Intersection	-.259	**.598**	-.441	.409
Time-Intersection	.486	-.009	**-.843**	-.048
Distance-Intersection	.521	.018	**-.835**	-.052
Reliability-Intersection	.358	.420	**-.808**	-.105
Comfort-Intersection	-.066	.294	**-.638**	.612
Comfort-Traffic	.072	.293	-.091	**.819**
Comfort-Facility	.179	.318	-.083	**.762**
Cronbach's alpha	.89	.74	.80	.79

* Variables with numbers in bold belong to each of the factors

The factor *Quick* captured the view of respondents that road and traffic features and cycling facilities are important for saving journey time, minimising journey distance and making a reliable journey. The factor *Safety* captured the view of respondents that road and traffic features, cycling facilities and intersections are important for safe cycling, while *Comfort* captured the view of respondents that road and traffic features and cycling facilities are important for comfort and pleasant riding. Finally, the factor *Intersection* captured the view of respondents that intersections on routes have a negative influence on saving journey time, minimising journey distance and making a reliable journey, as the loading factors in these variables have all minus numbers. All the four factors had a sufficient internal reliability (Cronbach's alpha[1]>0.70).

4.3.2.3 Cluster Analysis

A cluster analysis was conducted based on the identified factors from the factor analysis. New scores for each of the factors were calculated. The scores were the averages of the scores of the variables belonging to each factor.

The factor analysis identified the 4 factors and each one had a unique characteristic, so the study intended to make clusters on which the characteristics of the factors were reflected. K-mean and two-step clustering methods are suitable because hierarchical clustering does not allow pre-determined numbers of clusters. The study actually conducted both K-mean and two-step clustering with various pre-determined numbers of clusters. The study found that two-step clustering with 4 clusters performed better for the study as the numbers of cases were more evenly distributed through the clusters and more clearly reflected the characteristics of the factors identified.

Clustering produced 4 cyclist types by criteria for route choice: *Speedy Cyclists, Worried Cyclists, Negative-to-Intersection (NTI) Cyclists* and *Heavenly Cyclists*. Table 4.7 shows the mean scores of the factors for the four cyclist types. The mean values represent the attitude to each factor identified in the factor analysis.

The largest percentage of respondents (31.2%) belonged to *Speedy Cyclists*, who represent the cyclists who want to make a quick trip, whereas *Worried Cyclists* had 20.6% of respondents and represent the cyclists who pay more attention to the safety of routes and the comfort of riding. These two types are predictable, as reducing trip time and safety during a trip are always important issues for cycling.

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[1] Cronbach' alpha: A coefficient of internal consistency which with over 0.70 is acceptable as rule of thumb (Nunnally and Bernstein, 1994)

Table 4.7 Mean Scores of the Indexes for Criteria-based Cyclist Types

Factor	**1.*Speedy*** (31.2%)	**2.*Worried*** (20.6%)	**3.*NTI*** (25.7%)	**4.*Heavenly*** (22.5%)
Quick	$5.73^{2,3,4}$	$4.83^{1,3,4}$	$4.08^{1,2,4}$	$6.27^{1,2,3}$
Safety	$5.47^{2,4}$	$6.66^{1,3}$	$5.11^{2,4}$	$6.50^{1,3}$
Intersection	$4.93^{3,4}$	$4.70^{3,4}$	$3.05^{1,2,4}$	$5.92^{1,2,3}$
Comfort	$4.62^{2,4}$	$5.80^{1,3,4}$	$4.49^{2,4}$	$6.15^{1,2,3}$

Items in superscript indicate significant difference from each other (ANOVA post hoc analysis (Dunnett T3))

NTI cyclists had the second largest number of respondents. This type significantly thought that intersections do not contribute to route choice. They gave the lowest score to the index *Intersection* with 3.05, which is below a median score of 4, and so this means that intersections are not important for route choice concerns whereas all the other factors were higher than a score of 4.

Heavenly cyclists with the proportion of 22.5% gave very high score to all the factors. This group definitely required very high standard of cycling route environment in all aspects. Table 4.8 shows brief profiles of each cluster.

Table 4.8 Profiles of Criteria-based Cyclist Types

Type	**Profile**
Speedy	✓ Arriving at a destination fast is the most important criteria for the route. ✓ Safety of the route is also important, but comfort along routes is less important than the others
Worried	✓ Safety is the most important issue for cycling routes. ✓ Comfort in riding is also important. ✓ But quick arriving at a destination and intersections along routes are relatively less important.
NTI	✓ Intersections are not important issues at all for route choice ✓ They also relatively do not seriously consider all the criteria presented for their cycling routes
Heavenly	✓ Considering all the criteria is important for their routes

There are several key points from the results of clustering. Firstly, safety is always an important factor for cycling routes through all the clusters. This is particularly important even for *Speedy* cyclists. Making a safe journey is almost as important as quickly arriving at a destination. Therefore, it seems that safety concern is the fundamental factor for route choice regardless of cyclist types.

Secondly, there are certain cyclists (*NTI*) who especially dislike junctions. *NTI* cyclists have relatively low expectations for cycling environments. The averages scores of all the factors given by them were close to a median score of 4 except for the factor of safety. However, the score of the factor safety given by *NTI* was even lower than the scores of the other types.

Thirdly, comfort was correlated with the safety. The scores of the two factors had a similar pattern, so it can be assumed that feeling safe and feeling comfort are correlated positively.

Differences in the proportions of the types by gender and city were also examined (Table 4.9). More male respondents belonged to *Speedy Cyclists* and *NTI Cyclists*, while more female respondents belonged to the *Heavenly Cyclists*. However, the proportions for *Worried Cyclists* between males and females were very close to each other. In terms of differences by city, more respondents in Leeds belonged to *Speedy* and *NTI* cyclists, while more respondents in York were *Worried* and *Heavenly* cyclists.

However, Chi-Square tests indicated that there was no significant difference in the proportions of the cyclist types by gender and city. Although it was statistically not significant, from the fact that York had higher response rates from females, it can be assumed that female cyclists demand safer or better environments for their routes than male cyclists.

Table 4.9 Chi-square Test Results of Criteria-based Cyclist Types by Gender and City

Type	Proportion (%)		Chi-Square Tests	Proportion (%)		Chi-Square Tests
	Male	Female		Leeds	York	
Speedy	32.7	29.0	x^2 =3.824 df=3 p=.281	32.7	29.4	x^2 =2.301 df=3 p=.512
Worried	20.3	21.0		18.6	23.0	
NTI	27.5	22.8		27.4	23.5	
Heavenly	19.5	27.2		21.2	24.1	

4.3.3 Results of Segmenting Cyclists

4.3.3.1 Results of Segment by Confidence Level

Socio-demographics

Table 4.10 shows that there were statistically significant differences between the 4 groups by confidence level by gender. More male respondents were confident or very confident cyclists. As the confidence level increased from beginner level to the very confident level, the proportions of male respondents also increased while the proportions of females decreased. This indicates that female cyclists may be more careful and cautious about riding on roads and may have more difficulty in managing various circumstances on roads.

Although there was no statistical significance with the other characteristics, aged respondents seemed to have difficulty cycling along with vehicles on roads as 17% of the age group of 55-64 were at the beginner level. The proportion of that group was larger than the proportion of the same age groups at other levels. Another point was that more respondents under the titles of White Others and others were at the beginner level. From the experience of data collection, most respondents of these two groups were foreigners, so this tendency was caused by unfamiliarity with the environments of the road network in England.

Table 4.10 Chi-Square Test Results of Characteristics and the Segment by Confidence Level

Characteristic	Confidence Level				Chi-Square Test		
	Beginner (N=64)	*Unconfident* (N=100)	*Confident* (N=184)	*Very Confident* (N=93)	Chi-Square Value	df	Sig.
Gender					**27.719**	**3**	**.000***
Male	34%	57%	67%	72%			
Female	66%	43%	33%	28%			
City					2.339	3	.505
Leeds	56%	61%	52%	55%			
York	44%	39%	48%	45%			
Age					15.585	15	.410
18-24	14%	9%	17%	14%			
25-34	22%	27%	27%	19%			
35-44	23%	28%	17%	24%			
45-54	23%	28%	28%	32%			
55-64	17%	7%	9%	10%			
65+	0%	1%	2%	1%			
Employment					10.773	6	.096
Employed	83%	87%	72%	79%			
Unemployed	2%	1%	5%	3%			
Student	16%	12%	23%	18%			
Ethnics					11.106	6	.085
White British	78%	87%	88%	86%			
White others	16%	12%	10%	7%			
Others	6%	1%	2%	6%			
Education					9.182	6	.164
GCSEs/O'level/ CSE or less	6%	4%	4%	5%			
A-level/ BTEC national	14%	7%	13%	21%			
Degree/ Higher degree	80%	89%	83%	74%			
Driving Licence					3.888	3	.274
Yes	91%	90%	86%	82%			
No	9%	10%	14%	18%			
Accessible Cars					2.917	6	.819
0	25%	23%	28%	29%			
1	61%	55%	54%	55%			
2+	14%	22%	18%	16%			

* Significance at the 5% level

Cycling Behaviours

Table 4.11 shows statistical test results between the 4 clusters by confidence level regarding cycling behaviours. Respondents in *Very Confident* more cycled for commuting, utility and leisure/touring together. The proportions of respondents who cycled for the three purposes together increased as their confidence level was raised. Respondents in *Unconfident* (27%) and *Confident (15%)* more cycled for commuting only than the other types.

In terms of period of cycling and frequency of cycling, confidence level influenced the proportions of each of the behaviours. More confident respondents became more confident, they cycled longer and more frequently period and more frequently they cycled. More respondents in *Beginner* thought of themselves as inexperienced, while none of the respondents in *Very Confident* thought of themselves as inexperienced.

36% of respondents in *Very Confident* had experienced serious accidents or slight accidents requiring medical treatment, while only 15 % from respondents in *Beginner* had similar experiences. As respondents gained more confidence, they experienced more accidents. The proportion of near misses was decreased from 44% to 30% as confidence levels increased. This can be interpreted in two ways. Firstly, there are more chances to have accidents, as more confident cyclists cycle more; secondly, more confident cyclists tend to take risks, assuming that they can manage hazardous situations, which can lead to a bad outcome.

Table 4.11 Chi-Square Test Results of Cycling Behaviours and the Segment by Confidence Level

Cycling Behaviour	Confidence Level				Chi-Square Test		
	Beginner (N=64)	*Unconfident* (N=100)	*Confident* (N=184)	*Very Confident* (N=93)	Chi-Square Value	df	Sig.
Trip purposes					**39.340**	**18**	**.003***
Commuting	9%	27%	15%	8%			
Utility	2%	2%	2%	3%			
Commute+Utility	20%	14%	16%	17%			
Commute+Leisure	22%	25%	20%	17%			
Utility+Leisure	6%	2%	7%	4%			
Commute+Utility+ Leisure	28%	30%	37%	45%			
Others	13%	0%	3%	6%			
Period of cycling					**21.621**	**6**	**.001***
Under 1 year	9%	3%	5%	0%			
1-3 years	11%	19%	8%	5%			
Over 3 years	80%	78%	87%	95%			
Self-indicated cycling experience					**47.568**	**6**	**.000***
Inexperienced	17%	8%	2%	0%			
Experienced	25%	26%	17%	7%			
Very Experienced	58%	66%	81%	93%			
Frequency of cycling					**18.884**	**6**	**.004***
5+ per week	50%	55%	63%	67%			
At least 1 per week	30%	39%	31%	22%			
1~3 per month or less	20%	6%	6%	11%			
Accident experience					**27.388**	**12**	**.007***
No	22%	15%	11%	5%			
Near miss	44%	40%	36%	30%			
Slight accident without treatment	19%	29%	32%	29%			
Slight accident with treatment	9%	14%	14%	24%			
Serious accident	6%	2%	7%	12%			

* Significance at the 5% level

4.3.3.2 Results of Segments by Route Choice Criteria

Socio-demographics

Overall, there were just a few statistically significant differences regarding socio-demographic variables between the 4 segments in route choice criteria (Table 4.12). *Speedy Cyclists* had the highest percentage with the age of 18-24 and 35-44 while *Worried* and *Heavenly* cyclists had higher percentages in older categories (over 45 years old). *NTI Cyclists* had higher percentages with the ages of 25-34 and 45-54 while having lower percentages in the other categories than the other groups. *Speedy Cyclists* also had a relatively higher percentage in students than the other segments.

The results can be interpretable, as students who are usually young tend to become *Speedy* cyclists who focus on making quick trips. Age also makes cyclists become more careful and shifts their interests from quicker trips to safer ones. Although gender and city were not statistically significant, they probably influenced the proportions of the segments as the proportions of *Worried* and *Heavenly* cyclists were higher in York *(*51% for *Worried* and 48% for *Heavenly* respectively) and in females *(*40% for *Worried and* 47% for *Heavenly* respectively).

Table 4.12 Chi-Square Test Results of Characteristics and the Segments by Route Choice Criteria

Characteristics	Route Choice Criteria				Chi-Square Tests		
	Speedy (N=129)	*Worried* (N=85)	*NTI* (N=106)	*Heavenly* (N=93)	Chi-Square Value	df	Sig.
Gender					3.824	3	.281
Male	64%	60%	65%	53%			
Female	36%	40%	35%	47%			
City					2.301	3	.512
Leeds	57%	49%	59%	52%			
York	43%	51%	41%	48%			
Age					**34.947**	**15**	**.003***
18-24	22%	11%	9%	14%			
25-34	22%	26%	31%	17%			
35-44	27%	20%	17%	23%			
45-54	18%	31%	37%	30%			
55-64	11%	9%	6%	14%			
65+	0%	3%	0%	2%			
Employment					**15.794**	**6**	**.015***
Employed	71%	74%	86%	84%			
Unemployed	2%	7%	1%	2%			
Student	27%	19%	13%	14%			
Ethnics					9.9194	6	.163
White British	90%	81%	91%	80%			
White others	7%	13%	7%	16%			
Others	3%	6%	2%	4%			
Education					6.711	6	.348
GCSEs/O'level/ CSE or less	2%	7%	5%	7%			
A-level/ BTEC national	16%	12%	11%	8%			
Degree/ Higher degree	82%	81%	84%	85%			
Driving Licence					2.678	3	.444
Yes	85%	86%	84%	91%			
No	15%	14%	16%	9%			
Accessible Cars					10.194	6	.117
0	29%	31%	28%	20%			
1	60%	54%	47%	60%			
2+	11%	15%	25%	20%			

* Significance at the 5% level

Cycling Behaviours

Regarding cycling behaviours, differences between the segments were rather small. Only the period of having cycled (period of cycling) and self-indicated cycling experience were statistically significant. *Worried Cyclists* had a higher percentage of respondents in having cycled for 1~3 years, while *Heavenly* cyclists had more of a percentage of the respondents in having cycled for less than 1 year. This indicates that cyclists who have cycled for a relatively shorter period have more concerns about safety and better cycling environments.

In terms of self-indicated cycling experience, *Worried* and *Heavenly* cyclists had higher percentages in *Inexperienced* than the other two groups. *NTI Cyclists* had more of a percentage in *Very Experienced* than *Speedy Cyclists*, while there was a larger amount in *Experienced* for *Speedy Cyclists*. So overall *NTI Cyclists* were more experienced cyclists than the *Speedy* category.

Although it was not statistically significant, there are a few points to be mentioned. *Speedy Cyclists* more focused on commute cycling or utility cycling (42% in total) while *Heavenly Cyclists* more cycled for commuting, utility and leisure all together (43%). In terms of experience of having accidents, *Speedy* and *NTI* cyclists had more experiences of having serious accidents and slight accidents without medical treatments, while *Worried Cyclists* had more experience in having near misses.

Table 4.13 Chi-Square Test Results of Cycling Behaviours and the Segments by Route Choice Criteria

Cycling Behaviours	Route Choice Criteria				Chi-Square Tests		
	Speedy (N=129)	*Worried* (N=85)	*NTI* (N=106)	*Heavenly* (N=93)	Chi-Square Value	df	Sig.
Trip purposes					24.557	18	.138
Commuting	16%	17%	10%	20%			
Utility	2%	5%	0%	2%			
Commute+Utility	24%	13%	16%	12%			
Commute+Leisure	22%	22%	24%	14%			
Utility+Leisure	5%	7%	4%	5%			
Commute+Utility+ Leisure	26%	34%	39%	43%			
Others	5%	2%	7%	4%			
Period of cycling					**12.650**	**6**	**.049***
Under 1 year	4%	2%	4%	8%			
1-3 years	9%	18%	7%	4%			
Over 3 years	87%	80%	89%	88%			
Self-indicated cycling experience					**28.083**	**6**	**.004***
Inexperienced	2%	11%	2%	9%			
Experienced	26%	14%	16%	13%			
Very Experienced	71%	75%	82%	78%			
Frequency of cycling					6.380	6	.382
5+ per week	55%	59%	64%	63%			
At least 1 per week	36%	36%	26%	26%			
1~3 per month or less	9%	5%	10%	11%			
Accident experience					8.022	12	.783
No	13%	12%	9%	14%			
Near miss	34%	46%	36%	37%			
Slight accident without treatment	31%	26%	33%	26%			
Slight accident with treatment	14%	12%	14%	19%			
Serious accident	8%	4%	7%	4%			

* Significance at the 5% level

4.3.3.3 Relationship between Confidence Level and Cyclist Types by Route Choice Criteria

The relationship between the two different cyclist types was examined. Table 4.14 shows a summary of Chi-square tests results. The results indicate that there is statically significant difference in the distributions ($p<0.05$).

Table 4.14 Chi-square Test Results of the Cyclist Types by Route Choice Criteria and by Confidence Level

Segments	*Beginner* (N=60)	*Unconfident* (N=93)	*Confident* (N=173)	*Very confident* (N=81)	Chi-Square Tests
Speedy (N=128)	20%	34%	34%	32%	x^2 =23.766 df=9 p=.005
Worried (N=83)	30%	25%	20%	9%	
NTI (N=105)	15%	25%	27%	32%	
Heavenly (N=91)	35%	16%	19%	27%	

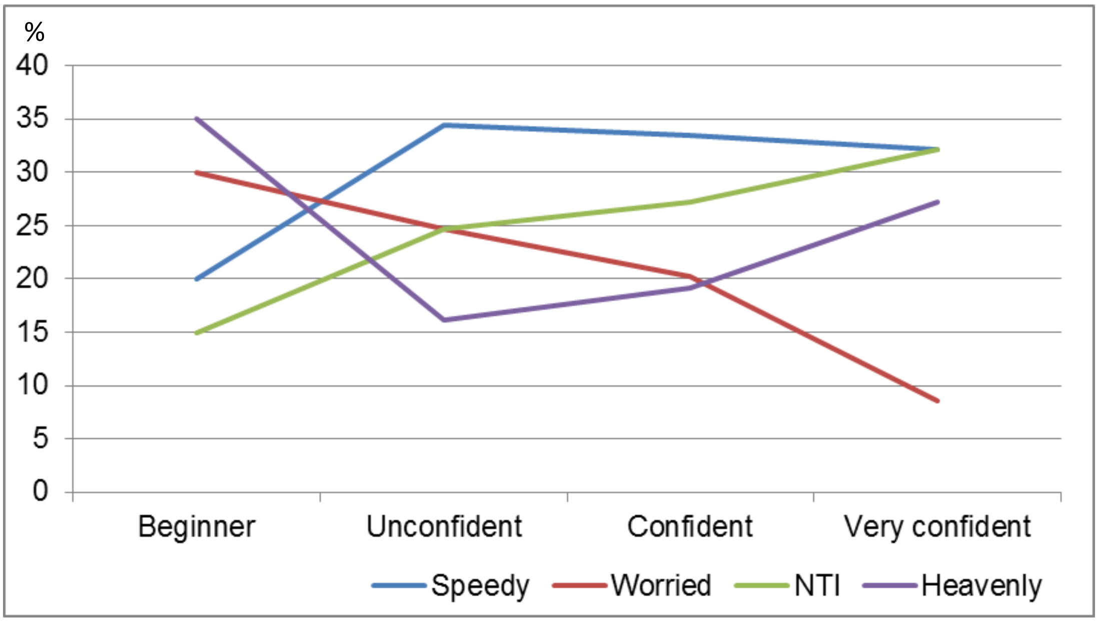


Figure 4.2 Changes of the Proportion of Criteria-based Cyclist Types by Increase of Confidence Level

Figure 4.2 more clearly shows changes in the proportions of each segment based on route choice criteria by the increase of the confidence levels of respondents. The proportions of *Worried Cyclists* dramatically fell down from 30% to 9% with the increase of the confidence level of respondents whereas the proportions of *NTI Cyclists* steadily increased from 15% to 32% with the increase of the confidence.

Changes of the proportions of *Speedy Cyclists* and *All Cyclists* are also very interesting. As the confidence level increased, the types showed different changes in proportion. The proportions of *Speedy Cyclists* increased at first then slightly decreased before seemingly becoming stable at 34%. On the other hand, the proportions of *All Cyclists* significantly decreased at first and then increased.

More discussions about the changes in the proportions of the criteria based cyclist types by confidence levels are presented in section 4.3.4.2.

4.3.4 Findings and Discussions

4.3.4.1 Segments by Confidence Level

The segments by confidence level shows that the confidence level is closely correlated with cycling behaviours. The development in confidence of cyclists for riding in traffic differentiated cycling behaviours such as purposes of cycling and frequency of cycling. However, the differences in the cycling behaviours may not be simply results of the increases of confidence as the relationship between cycling behaviours and development of confidence is more like a circle. For example, as cyclists cycled for longer period, they become more confident and skilful and then increase the frequency of cycling and cycles for more varieties of activity. This section discusses 3 key findings regarding the relationship between cycling behaviours and the development of confidence.

Self-indicated experience

There is a very interesting finding about the self-indicated experience. In the previous studies, the terms of experienced or inexperienced were rather unclear and defined by the researcher’s own judgement (Stinson and Bhat, 2005; Sener et al., 2009); however, the study shows a certain guide about judging the experience of cyclists.

Table 4.15 shows that the changes of the proportions of period of cycling were reasonably well matched with self-indicated experience, especially with *Inexperienced* and *Very Experienced*. The majority of *Under 1 year* belonged to the *Inexperienced* group and the proportion decreased by the increase of the experience, while the majority of *Over 3 year* belonged to

Very Experienced group and the proportion increased by the increase of the experience level. The largest number of *1-3 years* belonged to the *Experienced* group and the remaining proportion was distributed in the other groups with a little more for the *Very Experienced* group.

Table 4.15 Comparison of Period of Cycling and Self-indicated Experience, Cyclist Types by Confidence Level

	Period of cycling			Chi-Square Tests		
	Under 1 year	1-3 years	Over 3 year	Chi-Square Value	df	Sig.
Self-indicated experience				**152.747**	**4**	**.000***
Inexperienced	47%	22%	1%			
Experienced	32%	49%	14%			
Very Experienced	21%	29%	85%			

* Significance at the 5% level

This correlation indicates that 1 year seems a distinctive point between inexperienced and experienced. This is consistent with the study by Torrence et al. (2007) which defined experienced cyclists as those who had cycled for over 1 year. Furthermore, 3 years for a distinctive point between experienced and very experienced seems to be acceptable from the results, but this requires more evidence.

Experience of having accidents in the past

Confidence has correlation with the rate of experiencing accidents. The findings revealed that the increase in confidence caused a higher chance in exposing accidents. This is because more confident cyclists tend to take a risk while less confident cyclists tend to avoid them. Less confident cyclists cycle in a defensive manner. *Beginner Cyclists* and *Unconfident Cyclists* had much higher percentages of no experience of accidents with 22% and 15% respectively than more confident cyclists. This indicates a negative impact of becoming confident in cycling with vehicles on roads.

Table 4.16 Confidence Level and Accident Experience

Cycling Behaviours	Confidence Levels				Chi-Square Tests		
	Beginner	*Unconfident*	*Confident*	*Very Confident*	Chi-Square Value	df	Sig.
Accident experience					**27.388**	**12**	**.007***
No	22%	15%	11%	5%			
Near miss	44%	40%	36%	30%			
Slight accident without treatment	19%	29%	32%	29%			
Slight accident with treatment	9%	14%	14%	24%			
Serious accident	6%	2%	7%	12%			

* Significance at the 5% level

Female cyclists and confidence and cycling accidents

It is noticeable that gender was the only statistically significant variable for the differences between the confidence level groups. The number of female samples for the study was smaller than that of males. However, the proportions for female samples decreased by the increase of confidence levels from 66% to 28%. For *Beginner*, the percentage of females was larger than the percentage of males. Female cyclists are less confident than male cyclists in general.

The important point is the relationship among the experience of accidents, confidence level and gender. The proportion of females was correlated with the confidence level. The less confident groups had the lower accident rates and the higher rate of experiencing no accident and near misses. It can be concluded that although female cyclists are less confident, they are more careful and have lower chances of encountering accidents and can avoid potential mishaps. However, there have been no studies found which studied the relationship between female cyclists' behaviours and cycling accident rates, so more studies are needed about the relationship among female cyclists, accident involvement and defensive cycling strategy.

4.3.4.2 Segments by Route Choice Criteria

Not many differences were found between the segments regarding socio-demographics and cycling behaviours. Overall, *Speedy* and *NTI* cyclists showed similar patterns in many variables of socio-demographics and cycling behaviours while *Worried Cyclists* and *All Cyclists* showed similarities.

Speedy Cyclists were young, and many of them were students and focused on commuting or utility cycling, whereas *NTI Cyclists* were older and more cycled for commuting and leisure together. *NTI Cyclists* were also the most experienced and least unemployed. In terms of *Worried Cyclists* and *All Cyclists*, they were inexperienced and had cycled for shorter periods and had more proportions of females. The differences between *Worried Cyclists* and *All Cyclists* were small.

On the other side, the relationship between criteria based segments and the confidence based segments was clearly identified. The changes in the proportion of *Worried Cyclists* clearly indicate that the interests of cyclists greatly shift from safety to something else, such as saving time, through the increase of confidence, whereas the changes in the proportion of *NTI Cyclists* reflects the fact that passing a junction becomes a less difficult task with an increase of confidence, which may be a positive aspect of that increase. However, in considering frequent cyclist accidents at or near junctions (RoSPA, 2013), this trend notes that development of confidence is really always beneficial to cyclists.

The changes in the proportion of *Speedy Cyclists* clearly indicate what the real interest of cyclists is. Making a quick trip is normally the most important criterion, and it is only when people newly begin cycling that they pay more attention to safety or better environments etc.

In terms of *Heavenly Cyclists*, the changes reflect gaps of expected cycling and real cycling. Most of the new cyclists will expect to meet all the criteria. However, with gaining a little confidence, or in other words getting used to cycling, they recognise that meeting all the criteria is unrealistic and start prioritising. The proportion of this type increased again after becoming confident. That pattern may indicate that they have rooms to make a balance among expectations for their cycling routes or cycling activities as much as the increased confidence.

The study showed that the value of the segments based on route choice criteria is not with the differences in socio-demographics and cycling behaviours but with the relationship with confidence level and shifts of interests of cyclists for route choice.

4.4 Overall Preference for Route Factors

This section presents findings from the questionnaire analysis in respect to overall attitudes towards route factors. The section shows attitudes in importance and preference on road and traffic features and is followed by attitudes towards cycling facilities. It then presents attitudes about junctions and feeling unsafe from route factors. Finally, discussions about key findings are presented.

4.4.1 Attitudes towards Road and Traffic Features

4.4.1.1 Importance on Road and Traffic Features

A summary of the descriptive analysis for importance is presented in Table 4.17. Icy Surface in Winter was the most important feature with a mean score of 5.57, followed by Traffic Speed (5.49) and Cycling Facility(5.00). Vehicle Parked on Street and Gradient were the bottom two least important features with scores of 3.62 and 3.81 respectively. However, Icy Surface in Winter is the feature for winter only, so Traffic Speed and Cycling Facility were the most important factors for their choice through all seasons. HGVs, Available Lane Width, Off-road Paths and Traffic Volume were also importantly considered. These features were not significantly different from cycling facility in the mean scores. The other features were relatively less important for cyclists' consideration of route choice.

Table 4.17 Importance of Road and Traffic Factors

Feature	N	Mean	Std. Dev
Icy surface in winter	443	5.57	1.638
Traffic speed	443	5.49	1.534
Cycling facility	439	5.00	1.841
HGVs	447	4.97	1.579
Lane width	443	4.97	1.816
Off-road path	443	4.97	1.949
Traffic volume	445	4.90	1.669
Personal or area security	431	4.64	1.702
Buses	444	4.33	1.687
Surface quality	438	4.30	1.720
Scenery	443	4.23	1.798
Poor street lighting/Darkness	445	4.13	1.739
Traffic calming(20 mile zone)	440	4.07	1.735
Gradient	444	3.81	1.758
Vehicles parked on streets	446	3.62	1.618

4.4.1.2 Preference on Road and Traffic Features

The likelihood in choosing each of road and traffic features was also presented in Table 4.18. Routes with an Icy Surface in Winter were least preferred while routes with Wide Space Available were the most preferred. Cyclists also indicated that they highly avoid routes with Vehicles at High Speed, HGVs Frequently Running and Poor Personal or Area Security. Poor Surface, Large Traffic Volume and Poor Street Lightings were the features that respondents did not prefer, but they were very close to a median score of 4.0, so the preference about those features were more like neutral.

On the other side, the features with relatively good conditions were highly preferred including Wide Space on Lane, Moderate Downhill, Good surface, Traffic calming (20 mile zone), Good Scenery and Steep Downhill. Even relatively bad conditions for cycling such as On-street Parking, Steep Uphill, Buses Running Frequently and Narrow Space on Lane were fairly acceptable according to the mean scores. Interestingly, moderate uphill was more preferred than steep downhill.

However, the indicated preferences do not mean cyclists will choose or not choose a route with the features because the importance for each feature is rather different from the preferences. This is more discussed in section 4.4.5.

Table 4.18 Likelihood to Choose Road and Traffic Features

Feature	N	Mean	Std. Dev
Icy surface in winter	442	2.65	1.626
High traffic speed	445	3.14	1.733
Frequently running HGVs	438	3.46	1.649
Poor personal or area security	422	3.47	1.691
Poor surface	431	3.82	1.733
Large traffic volume	444	3.95	1.826
Poor street lighting in darkness	445	3.98	1.682
Narrow space on lane	441	4.68	1.593
Frequently running buses	439	4.69	1.540
Steep uphill	442	4.76	1.637
Vehicles parked on streets	439	4.88	1.495
Steep downhill	442	5.33	1.542
Good scenery	438	5.34	1.605
Traffic calming (20 mile zone)	433	5.36	1.328
Moderate uphill	444	5.62	1.272
Good surface	430	5.82	1.563
Moderate downhill	441	5.90	1.188
Wide space on lane	436	6.23	1.124

4.4.2 Attitudes towards Cycling Facilities

Overall, respondents were highly interested in using cycling facilities regardless of types (Table 4.19). Cycle lanes were the most preferred facility, followed by segregated cycle paths and off-road paths. A few study supported that cycle lanes were more preferred than segregated cycle paths (Stinson and Bhat, 2003). However, the majority of studies concluded that cyclists preferred separated lanes from roads over cycle lanes on roads (Taylor and Mahmassani, 1996; Wardman et al., 1997; Abraham et al., 2002; Hunt and Abraham, 2007). This is more discussed in section 4.4.5.

Cyclists preferred cycle lanes than shared bus lanes or shared pedestrian paths. This is probably because cyclists think on-road cycle lanes are not much different from cycle lanes and are still part of the road network.

Table 4.19 Preferences for Cycling Facilities

Facility types	N	Mean	Std. Dev
Cycle lane	445	6.27	1.205
Segregated cycle path	444	6.15	1.387
Off-road path	443	5.93	1.478
Advanced stop line	419	5.80	1.545
Bridge with a facility only for cycling	433	5.64	1.697
Cycle crossing facility	419	5.38	1.774
On-road cycle lane	440	5.23	1.467
Shared pedestrian path	446	4.67	1.915
Shared bus lane	438	4.56	1.819

Discontinuity of cycling facilities is often an issue raised by cyclists, so this matter as well as cycle parking spaces nearer to cycling routes was also questioned (Table 4.20). Cyclists fairly strongly agreed that continuous provision of cycling facilities is important, reaching a mean score of 5.37. Continuity of cycling facility influences the choices of routes by cyclists in positive ways (Stinson and Bhat, 2003), especially for long distance commuters (Sener et al., 2009).

They also indicated that cycle parking spaces near to routes are fairly positive for route choice, but not strong. It seems that bicycle parking is a potential demand of cyclists, but only at a destination. Secured parking for bicycles is a sensitive matter for young cyclists and cyclists who have expensive bicycles (Hunter and Abraham, 2007). However, although the finding from the study shows a relatively positive score with that, it seems not a matter of route choice but of convenience at destinations and cycling activity itself.

Table 4.20 Continuity of Cycling Facilities and Bicycle Parking

Statement	N	Mean	Std. Dev
The continuous provision of cycling facilities is more important than the provision of cycling facilities at certain sections of a route.	408	5.37	1.608
I prefer a route near to a cycle parking facility	425	4.40	1.713

4.4.3 Attitudes towards Junctions

Junctions are an important feature on roads, especially for safety, as 70% of reported cycling accidents occurred at junctions or closed areas (RoSPA, 2013). The questionnaire examined the behaviours of cyclists at a junction and what features of junctions are important for decisions when using a certain junction.

The results in Table 4.21 show that cyclists did not think that junctions, regardless of type, were a significant barrier for cycling. Although respondents tended to more avoid roundabouts, they usually did not avoid junctions. However, respondents seemed to be more confident with signalised junctions than the others.

Table 4.21 Behaviours at Junction

Behaviour of avoiding	N	Mean	Std. Dev
Roundabout	443	3.33	1.985
Junctions frequently used by vehicles	442	3.02	1.794
Junction where I need to make a right turn	444	3.01	1.866
Give-way junction	444	2.41	1.493
Signalised junction	445	2.34	1.525

Table 4.22 shows the importance of features of junctions and their consideration for uses. *The complexity of an intersection* was given the highest score with 4.69 and followed by *Advanced stop line*, *Number of vehicles making a turn* and *Size of an intersection* in order. However, the scores were not high, only close to a median score of 4, which means that they are not critical factors for consideration in route choice.

Table 4.22 Importance of Junction Features for Decision of Use

Feature	N	Mean	Std. Dev
Complexity of intersection	442	4.69	1.861
Advanced bicycle stop line	437	4.26	1.921
A number of vehicles making a turn	438	4.22	1.890
Size of intersection	441	4.21	1.815

4.4.4 Feeling Unsafe from Route Features

The features on cycling routes that cause cyclists to feel unsafe were analysed (Table 4.23). Higher scores mean that cyclists feel more unsafe. Overall attitudes were very similar to the attitudes towards the preference on road and traffic features.

High traffic speed (5.92) was on the top of the features which made cyclists feel unsafe with, followed by *Not enough distance from vehicle* (5.77), *HGVs or buses* (5.52), *Riding on roads in poor weather* (5.52), *Riding without proper lights in dark* (5.19) and *Large traffic volume* (5.04). Most of the features were traffic-related, with only 2 that were different: weather and lightings which is related with time of day.

Table 4.23 Feeling Unsafe from Route Features

Features	N	Mean	Std. Dev
High traffic speed	446	5.92	1.224
Not enough distance from vehicles	445	5.77	1.308
HGVs or buses	446	5.52	1.332
Riding on roads in poor weather	443	5.52	1.381
Riding without proper lights in dark	429	5.19	1.672
Large traffic volume	445	5.04	1.349
Pedestrians appearing suddenly	442	4.89	1.455
Poor surface quality	419	4.53	1.668
Changing a lane in traffic	443	4.43	1.548
Making a right turn at a junction	438	4.25	1.532
Vehicles parked on street	445	4.18	1.447
Environment of areas nearby route	403	4.14	1.467
Going forward at junction	440	3.25	1.534
Steep downhill	440	3.13	1.525
Steep uphill	438	2.87	1.473
Moderate uphill	440	2.52	1.438

Pedestrians, *Poor surface quality*, *Changing a lane in traffic* and *Making a right turn at a junction* were the features that made cycling inconvenient rather than unsafe. Parked vehicles and nearby environments on route hardly influence the safety of routes. There are 3 gradient-related features: steep downhill, steep uphill and moderate uphill, and going forward at a junction did not make respondents feel unsafe with them.

Cyclists felt relatively safe when they changed a lane in traffic. As traffic related features made respondents feel unsafe, it would be reasonable that they felt this when they change a lane in traffic, which is directly related with vehicles' or drivers' reactions. However, the indication from respondents was different. It seems that feeling unsafe from traffic is more influenced by a psychological matter than physical features or behaviours on site.

4.4.5 Findings and Discussions

There are 3 main points to discuss in this section based on the findings from the above sections: Key factors for route choices, the relationship among traffic, safety, and cycling facilities, and finally the contradictory attitudes of cyclists towards junctions in order.

Key factors for route choices

Figure 4.3 shows the scatter plot of the importance and preference of measured features of cycling routes. The figure clearly shows what features are more or less important and more or less preferred. The part on the top right side (Part 1) shows important and preferred cycling route features while the part on the bottom right side (Part 2) shows important but not preferred ones. The part on the top left (Part 4) shows not important but preferred features while the part on the bottom left side (Part 3) shows not important and not preferred features.

Being rather predictable, cycling facilities, wide space on road lane and off-road paths were included in part 1 while large traffic volume, high traffic speed, HGVs, the place having poor security and icy surfaces in winter were included in part 2.

All the features in parts 1 and 2 were traffic or cycling facility related features except for poor personal or area security. This indicates how important traffic and cycling facilities are for route choices. Cycling facilities including wide space on a road lane influence cyclists' choices in a positive way, while traffic such as large volume, high speed, HGVs and buses influence in a negative way.

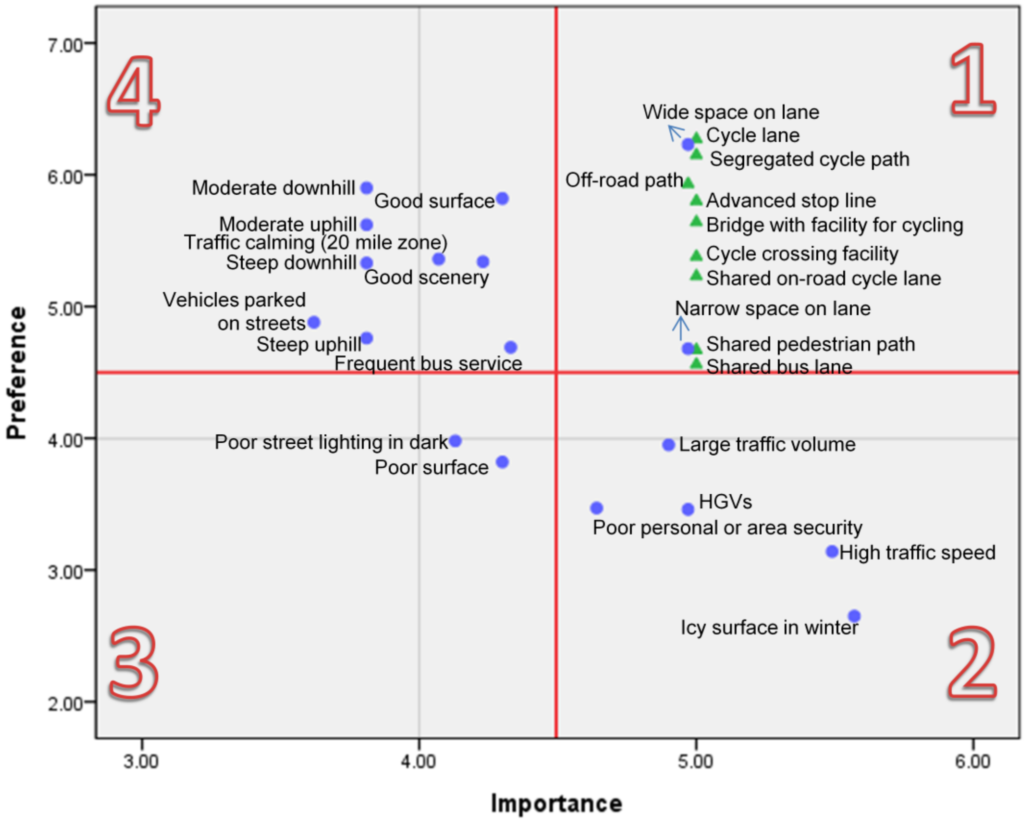


Figure 4.3 Scatter Plot of Importance and Preference for Cycling Route Features

The results found that high traffic speed and large volume are both negatively important influential factors for route choice (Sener at al., 2009). However, a more important finding is that the importance of high speed traffic is far greater than the importance of large traffic volume. However, Sener et al. (2009) found different findings from the study regarding traffic volume and speed, stating large volume was a more important factor than high speed traffic. These differences reflect different road environments or different characteristics of cyclists between the UK and USA. Further interesting findings regarding traffic volume and speed are presented in the qualitative part of the study (see section 6.3.1)

In terms of HGVs and buses, both vehicles are bigger than ordinary cars. However, the reactions from cyclists were different. HGVs are far more important and the factor that cyclists should avoid, while buses are rather neutral and fairly acceptable for cycling together. This may be because buses are users who drive more carefully on roads than HGVs, although the differences in behaviours of the drivers between buses and HGVs have not been studied yet. (see section 6.3.3 for bus lanes).

The factors on parts 3 and 4 are all optional, which means that if it is good, it will be taken but if it is bad, it will be taken only when the other mandatory factors are satisfied. Therefore these factors will make cyclists feel more or less convenient or enjoyable when cycling and will not significantly influence actual route choice. The previous studies agree that hilliness, surface and on-street parking are all different in preference depending on the conditions, but they are all not critical factors (Stinson and Bhat, 2003; Sener et al. 2009). As shown Figure 4.3, the study also found that preferences regarding those factors are different depending on the conditions. So the findings are consistent with the findings from the previous studies, but with limitations. However, we still require more studies about these factors to establish whether or not they are really important for route choices.

All the factors in Part 1 are basically cycling facilities or similar ones. Cycling lanes, segregated cycle paths and off-road paths were top 3 in preference in order. The study revealed that cycle lanes are more preferred than segregated cycling paths, which is inconsistent with many previous studies which found that segregated paths were more preferred (Taylor and Mahmassani, 1996; Wardman et al., 1997; Abraham et al., 2002; Hunt and Abraham, 2007). However, Stinson and Bhat (2003) found that cyclists preferred separated paths than cycle lanes.

Wider lanes were preferred as cycle lanes and segregated cycle paths, as wider space acts like cycle lanes. A few studies found that cyclists like to use wider road lanes than cycle lanes (Sener et al., 2009), or at least prefer them to ordinary size lanes (Stinson and Bhat, 2003).

The differences in the findings between the studies can be possibly caused by the characteristics of study samples. This study and the study by Stinson and Bhat recruited only commuter cyclists (utility cyclists) while most of the other studies recruited non-cyclists too. Therefore the strong favour of non-cyclists to separated paths may be reflected in the results.

Separated paths were more desired than off-road paths (Taylor and Mahmassani, 1996; Wardman et al. 1997; Abraham et al., 2002). However, shared pedestrian paths were not preferred. Off-road paths are usually shared with pedestrians, so depending on the types of off-road paths, the preferences of cyclists will be divided.

As a consequence, current cyclists tend to prefer cycle lanes, segregated cycle paths, wider lanes and off-road paths for practical reasons. The findings are important in the aspect of building cycling networks. Building cycle lanes or more space will be cheaper than providing new separated paths. According to the results, even providing a little more space on a road lane will improve the use of the roads by cyclists. This measurement can be an alternative to providing cycle lanes depending on road layouts and traffic circumstances. However, this policy may not be able to attract non-cyclists.

In terms of shared lanes with buses or vehicles, although they are considered as important factors, they are not much preferred; rather they are the facilities that are better than nothing.

Traffic, Safety, and Cycling Facility

Table 4.24 compares the scores of the factors of Feeling Unsafe and Likelihood to Choose. Most of the factors having a high score are traffic related factors. These results clearly show that cyclists are more sensitive to traffic because of risks from vehicles (Winters and Teschke, 2010; Hopkinson and Wardman, 1996; Bovy and Bradley, 1985).

Table 4.24 Comparison of Scores of the Factors between Feeling unsafe and Likelihood to Choose

Feeling unsafe	Mean	Likelihood to choose	Mean
High speed traffic	5.92	High traffic speed	3.14
Not enough distance from vehicles	5.77	Narrow space on lane	4.68
HGVs or Buses	5.52	Frequent HGVs	3.46
Riding on roads in poor weather	5.52	Icy surface in winter	2.65
Riding without proper lights in dark	5.19	Poor personal or area security	3.47
Large traffic volume	5.04	Large traffic volume	3.95

On the other hand, Figure 4.3 shows interesting distributions of the factors. Cycling facilities are located in Part 1 while traffics and safety related factors are located in Part 2; noticeably, they are located on the opposite sides of each other. The questionnaire analysis does not provide a clear picture about why cycling facility is more important and preferred by cyclists. However, Figure 4.3 allows us to assume a possible theory that the role of a cycling facility is to remedy risks from traffics and to increase the perceived safety of cyclists (Dill and Gliebe, 2008). Although not many studies are found which studied the relationship between safety and cycling facilities, a few modelling studies revealed that the presence of a cycle lane or wider space increases comfort levels in cycling (Landis et al., 1997; Harkey et al., 1998; Landis et al., 2003).

The relationship between cycling facilities and safety and the role of cycling facilities are more clearly found through the qualitative part (see section 6.4.1).

Are really Junctions not important?

The analysis results for importance of the features of junctions more clearly shows the trend that respondents did not think of junctions as a considerable factor in route choice (see Table 4.22). Complexity of an intersection was given the highest score among the features, but the score was just 4.69 (which is close to a median score of 4).

However, Figure 4.3 shows a little different story about junctions. Cyclists think that cycling crossing facilities are important and preferred, and furthermore, advanced stop lines are highly preferred. These differences indicate that the important point with junctions is what cyclists emphasise regarding junctions for their consideration for route choice: a quick journey or safe journey. The low scores in the behaviours and the features of junctions may be mostly due to a disadvantage in trip time while the reason to prefer advanced stop lines and cycling crossing facilities is mainly due to safety or convenience. This can be supported by the study of Dill et al. (2010) in which advanced stop lines (bike box) increased awareness and safer driving for both drivers and cyclists.

Although this could not be proven in the quantitative part of the study, it was in the qualitative part (see section 6.3.4 and 6.3.5)

4.5 Differences in Preferences to Route Factors by Gender

In this section, the differences of attitudes of cyclists by gender are presented. Key findings are at first described with interpretations about the meanings of the findings before then moving onto discussions about the key findings.

All the tables in this section show mean values instead of median values which are usually used for non-parametric analysis because median values do not clearly provide differences of measured scores between the sample groups.

Only statistically significant variables are summarised in tables, so full statistics results are provided in Appendix 4-1.

4.5.1 Importance on Road and Traffic Factors

Major differences between males and females appeared to be of importance in road and traffic factors. Table 4.25 shows the comparison of ranks in importance of each factor between males and females.

Table 4.25 Female Vs Male in Importance on Road and Traffic Features

Female		Male	
Score	**Importance Rank**	**Importance Rank**	**Score**
5.79	Icy surface in winter	Icy surface in winter	5.43
5.70	Traffic speed	Traffic speed	5.36
5.41	Off-road path	Cycling facility	4.89
5.20	Lane width	HGVs	4.85
5.17	Cycling facility	Lane width	4.82
5.17	Traffic volume	Traffic volume	4.73
5.16	HGVs	Off-road path	4.68
5.07	Personal or area security	Scenery	4.35
4.68	Poor street lighting/Darkness	Personal or area security	4.35
4.47	Surface quality	Buses	4.25
4.46	Buses	Surface quality	4.18
4.35	Traffic calming (20 mile zone)	Traffic calming (20 mile zone)	3.88
4.09	Gradient	Poor street lighting/Darkness	3.77
4.05	Scenery	Gradient	3.63
3.67	Vehicles parked on streets	Vehicles parked on streets	3.59

Icy surface in winter and traffic speed were the top 2 features in importance for route choice for both genders. However, female cyclists thought off-road path and lane width were more important while male cyclists considered cycling facilities and HGVs to be more important. Furthermore, female cyclists importantly took into account safety related circumstances such as personal or area security and poor street lightings/darkness while male cyclists put scenery on a higher rank than safety and security circumstances. The results clearly show that female cyclists pay more attention to safety both in terms of vehicles and personal security.

Female cyclists have more concerns about safety than male cyclists (Garrad, 2003; Byrnes et al., 1999) and are more like to be completely separated from vehicles than men (Krizek et al., 2005). Female cyclists prefer off-road paths than male cyclists (Winters and Teschke, 2010; Heech et al., 2012). Moreover, the gaps of the scores of preference between females and males became larger as route conditions got worse, such as with major streets with parked cars. Therefore, by these reasons, female cyclists highly ranked safety related factors such as off-road paths more than male cyclists.

4.5.2 Differences in Attitudes for Route Factors by Gender

Table 4.26 shows a summary of differences by gender in preferences about the factors for route choice. Only the attributes which have a statistical significance are presented in the table.

Table 4.26 Comparison in the Attitudes of Cyclists by Gender

	Female	Male	Sig.
Likelihood to choose			
Road and traffic circumstance			
Icy surface in winter	2.34	2.86	p=.000
High traffic speed	2.88	3.31	p=.005
Poor personal or area security	2.89	3.84	p=.000
Frequently running HGVs	3.22	3.61	p=.013
Poor street lighting in dark	3.44	4.33	p=.000
Poor surface	3.49	4.04	p=.001
Steep uphill	4.39	5.02	p=.000
Frequently running buses	4.41	4.87	p=.004
Steep downhill	5.09	5.50	p=.004
Wide space on lane	6.30	6.19	p=.044
Cycling facility			
Cycle lane	6.49	6.12	p=.000
Segregated cycle path	6.31	6.04	p=.027
Off-road path	6.11	5.81	p=.025
Cycle crossing facility	5.83	5.10	p=.000
Shared pedestrian path	5.05	4.43	p=.000
Shared bus lane	4.19	4.79	p=.001
Continuity of cycling facility	5.59	5.23	p=.039
Junctions			
Behaviour			
Avoiding roundabout	3.60	3.15	p=.034
Importance of feature			
Complexity of intersection	4.97	4.51	p=.004
Advanced stop line	4.47	4.13	p=.046
Feeling unsafe			
High traffic speed	6.15	5.77	p=.000
Riding on roads in poor weather	5.87	5.30	p=.000
HGVs or buses	5.81	5.33	p=.000
Riding without proper lights in dark	5.61	4.92	p=.000
Large traffic volume	5.37	4.83	p=.000
Changing lane in traffic	4.74	4.23	p=.000
Making right turn at junction	4.51	4.08	p=.003
Environment of areas nearby route	4.47	3.94	p=.000

4.5.2.1 Attitudes to Road and Traffic Factors and Cycling Facilities

In terms of preference of road and traffic features, female cyclists gave a lower score to each factor with a poor condition while they gave a higher score to each factor with a good one. Most cases having a statistically significance were the factors with a poor condition. This supports that women are more risk averse than men.

In terms of the attitude to cycling facilities, as expected female cyclists more preferred using cycling facilities than male cyclists. This finding is consistent with the idea that women cyclists are willing to spend more time using cycling facilities than men (Krizek et al., 2005).

However, there were two interesting findings from the results. Firstly, male cyclists far preferred shared bus lanes while female cyclists preferred shared pedestrian paths. These results reveal the differences in the interests in cycling routes between men and women. Male cyclists are interested in quicker trips as they are more willing to ride with buses while female cyclists are interested in safe trips as at least sharing spaces with pedestrians is less risky.

The second interesting finding was that the score for cycling crossing facilities given by female cyclists are much higher than by male cyclists. The study revealed that any junction related scores were low and junctions tended to be ignored by cyclists. However, at least for female cyclists, junctions may be a matter which should be considered.

4.5.2.2 Attitudes towards Junctions

Roundabouts were the only type which had a significant difference in preference between male and female cyclists. Female cyclists significantly tended to avoid roundabouts more than male cyclists. However, this does not mean that roundabouts are a big problem for female cyclists because the score given to this attribute was relatively low.

There was inconsistency between the findings from the attitudes towards cycling facilities and junctions. There was high preference towards cycle crossing facilities, but cyclists did not have much difficulty in crossing junctions. This difference may be caused because the high demand for cycle crossing facility would be not a mandatory demand but rather just optional for a little more convenience.

4.5.2.3 Feeling Unsafe from Route Features

There were significant differences in degrees of feeling unsafe with route features between male and female cyclists. Female cyclists felt significantly more unsafe than male cyclists in the factors which were mostly related with traffic and security.

Females felt more unsafe when making right turns at a junction than males. This result indicates that junctions are a rather complicated matter, at least for female cyclists. This could be because junctions are not too difficult to cross but risk always exists there. Moreover, females are more sensitive to safety so they have higher demands on cycle crossing facilities to reduce potential danger.

Although stronger feelings about safety by female cyclists are highlighted, it does not mean that male cyclists do not feel unsafe with the current cycling environments. The ranks of the route features in feeling unsafe were almost similar between males and females. When male cyclists showed caution to a certain feature, female cyclists also had a similar but stronger caution.

4.5.3 Discussion in Differences by Gender

The findings about the differences in gender strongly indicate that most of the differences occur because of the different degree of the attitudes about safety of cycling routes.

Female cyclists are more sensitive to risks on routes, and potential risks are the main deterrent to cycling for women (Garrad, 2003; Garrard et al., 2006). Exactly the same theory applies to route choices. Females are more careful about the conditions along cycling routes and they have more concerns about infrastructures and road conditions (Krizek et al., 2005). Therefore this tendency is reflected in the stronger preferences for cycling facilities and the lesser preferences for bad conditions of road and traffic features.

By this reason, making cycling routes safer is important for cyclists, especially for women. Men cycle more than women and are more active in various cycling activities, as well as more skilful and confident in managing various situations on roads. In terms of cycling, women are a weaker and disadvantaged target, so making women cyclists more comfortable is an important task for the increase in cycling uses for transport purposes.

The study indicated that there are higher preferences towards cycling facilities by female cyclists, and Figure 4.3 shows a clue towards how potential risks and fear from cycling alongside vehicles can be remediable. Cycling facilities are a key for this. More optimistically, females are willing to spend more time for better facilities than males (Krizek et al., 2005), so targeting females and designing and providing facilities for women is better for the overall strategy of planning better cycling routes as well as promoting cycling.

4.6 Differences in Preferences to Route Factors by City

In this section, differences of attitudes between cyclists in Leeds and York are presented. Leeds and York have different geographical features such as the size of the city and population. Cycling activities and the atmosphere for cycling are also far different. It is very interesting to discover differences or homogeneity through different cities in the same country.

Key findings are at first described with interpretations about the meanings of the findings before then moving onto discussions about the key findings.

All the tables in the section show mean values. Statistically significant variables are summarised in tables, so full statistics results are provided in Appendix 4-2.

4.6.1 Importance on Road and Traffic Factors

Major differences between Leeds and York appear to be of importance in terms of road and traffic factors. Table 4.27 shows the comparison of ranks in importance of each factors between the two cities.

The key factors differences were off-road paths, lane width, surface quality, and traffic calming. Respondents in York put off-road paths and lane width on a high rank while respondents in Leeds put cycling facility and HGVs on a higher rank than off-road path and lane width. Off-road paths were ranked low in Leeds (7^{th} place) but high in York (3^{rd} place). This reflects the traffic environment of York and Leeds. Leeds is a bigger city than York, with more traffic and faster vehicles on a wider road network, while York is an old and famous tourist city whose roads are narrow. In addition, York has a good riverside path for multiple uses by pedestrians and cyclists which passes through the city central area, but Leeds does not have such a path. Therefore these different environments might influence the importance of the factors.

Table 4.27 York Vs Leeds in Importance of Road and Traffic Features

York		Leeds	
Score	**Importance Rank**	**Importance Rank**	**Score**
5.76	Icy surface in winter	Icy surface in winter	5.42
5.65	Traffic speed	Traffic speed	5.36
5.28	Off-road path	Lane width	5.02
5.09	Cycling facility	Cycling facility	4.93
5.02	HGVs	HGVs	4.93
4.94	Traffic volume	Traffic volume	4.87
4.91	Lane width	Off-road path	4.71
4.65	Personal or area security	Personal or area security	4.63
4.45	Surface quality	Buses	4.44
4.25	Traffic calming (20 mile zone)	Scenery	4.27
4.20	Buses	Surface quality	4.17
4.19	Scenery	Poor street lighting/Darkness	4.11
4.15	Poor street lighting/Darkness	Traffic calming (20 mile zone)	3.92
3.87	Gradient	Vehicles parked on streets	3.79
3.43	Vehicles parked on streets	Gradient	3.76

There were similar patterns with relatively less important factors. Personal or area security and poor street lighting/darkness in York were ranked relatively higher (but the latter was in the middle of the rankings overall) than in Leeds whereas scenery was ranked much higher in Leeds (8th) than in York (14th). These differences are also due to the environment of the cities: a good tourist city with lots of green areas and historic sites vs a commercial city with grey buildings in the centre.

4.6.2 Differences in Attitudes to Route Factors by City

Table 4.28 shows a summary of the differences by city in preferences for the factors for route choices. Only the attributes which have a statistical significance are presented in the table.

4.6.2.1 Attitudes towards Road and Traffic Factors and Cycling Facility

Respondents in York preferred high traffic speed and buses significantly less than in Leeds, whereas they actively liked vehicles parked on streets, traffic calming, good surface and wide space on lanes. This is interesting for two points: Firstly, the factors with a significant difference have a good condition, such as wide space, good surface and traffic calming. It is not clear why cyclists in York prefer such factors. However, it can be interpreted in two opposite ways: Firstly, in general, it is believed that York has a better environment for cycling, so cyclists there have already experienced better quality of given factors such as surface. Therefore they prefer those good conditioned factors. On the other hand, the actual quality for the factors are poor in York and cyclists in York have experienced bad quality for those factors, and so they want better quality for those factors. The real reasons should be checked with the real conditions of those factors for each city, but such a task is beyond the scope of this study.

Table 4.28 Comparison in the Attitudes of Cyclists by City

	York	Leeds	Sig.
Likelihood to choose			
Road and traffic circumstance			
High traffic speed	2.89	3.36	p=.003
Frequently running buses	4.38	4.95	p=.000
Vehicles parked on street	5.17	4.64	p=.000
Traffic calming (20 mile zone)	5.53	5.22	p=.014
Good surface	6.10	5.58	p=.001
Wide space on lane	6.34	6.15	p=.019
Cycling facility			
Off-road path	6.11	5.78	p=.029
Cycle crossing facility	5.65	5.18	p=.008
Shared pedestrian path	4.93	4.46	p=.011
Route near to bicycle parking	4.80	4.06	p=.000
Shared bus lane	4.17	4.88	p=.000
Junctions			
Behaviour			
Avoiding roundabout	3.12	3.50	p=.039
Feeling unsafe			
Making right turn at junction	4.10	4.37	p=.049
Vehicles parked on street	4.00	4.34	p=.015

Cyclists in York were more tolerant towards parked vehicles on streets. This may indicate that parked vehicles are not a serious problem in York, as the amount of traffic in York is far smaller or at least more so than in the city centre area in Leeds. On the other hand, parked vehicles are really a disturbing problem for cycling in Leeds because of frequent moving in and out to avoid such parked cars, as more parked cars on the streets in Leeds can cause more risky manoeuvres.

The environment of city seems to make people in the city more or less tolerant to pedestrians or buses. Cyclists in York preferred using cycling facilities except for shared bus lanes. It is interesting that shared bus lanes were the least preferred facility in York while shared pedestrian paths were the least preferred facility in Leeds. These results show complete different attitudes towards buses and pedestrians between the two cities: York is more friendly to pedestrians while Leeds is more tolerant to buses. These tendencies are caused by fundamental differences in the road network environment of each city.

There are many bus lanes in Leeds and cyclists can use such wide spaces like cycle lanes. Furthermore, the bus lanes are usually empty except for peak times whereas York has narrow roads over the city and does not have many bus lanes. Furthermore, the road network, including bus lanes, are always packed with vehicles, especially in the city centre. On the other hand, York is always packed with pedestrians, locals and tourists. Therefore cyclists in York are more tolerant to pedestrians and conflicts with pedestrians.

4.6.2.2 Attitudes towards Junctions

Only avoiding roundabouts had a statistically significant difference between cyclists in Leeds and in York. Cyclists in Leeds more tended to avoid roundabouts than in York. This indicates that cycling with vehicles in Leeds is not easy, especially with roundabouts, though crossing junctions are relatively not a serious problem overall . This is more clear with the results in feeling unsafe below.

4.6.2.3 Attitudes towards Route Features for Safety

There are only two variables: vehicles parked on the street and making a right turn at a junction had significant differences in feeling unsafe between cyclists in Leeds and York. Cyclists in Leeds felt rather more unsafe. Although the overall scores were not high, these results are meaningful together with the result in section 4.6.2.2.

The study showed that junctions were generally not a serious barrier for route choice. However, the two factors, making right turn at a junction and roundabouts, together indicate that crossing a junction in Leeds is at least more problematic than in York.

Vehicles parked on the street were thought of as more unsafe by cyclists in Leeds. This also indicates that parked vehicles are one of the sources that cyclists feel risk with, as they need to move in and out to avoid them. This behaviour is riskier in Leeds than in York because usually vehicles move faster in the former on wider roads than in the latter.

4.6.3 Discussion in Differences by City

The identified differences showed that the preferences were strongly influenced by the environment of the individual cities. The most significant differences were the attitudes towards off-road paths, shared bus lanes, shared pedestrian paths and parked vehicles on streets. All the preferences reflect the practical experiences and active adaptation to the environment of the cyclists of the cities.

York has more friendly environments for pedestrians, and that environment makes cyclists more positive towards sharing space with pedestrians. In contrast, Leeds is more friendly for drivers, and that makes cyclists more positive towards using bus lanes. York has better off-road paths which are shared with pedestrians. Cyclists in York may have good experiences for a long time and get used to sharing the spaces with pedestrians, even though this was not exactly intended by the cyclists from the first time. In contrast Leeds has the better bus lane network and the cyclists have already used the bus lanes as if they were cycle lanes. Although bus lanes are not designed for cycling and probably more risky, but they provide faster moving practically.

Another explanation for the differences is that the results are influenced by the attitudes of female cyclists. Half of the samples in York were female while that gender only covered around 30% of the samples in Leeds were. In section 4.5.1, it was shown that females cyclists ranked off-road paths and safety related factors high. Therefore the attitudes of females cyclists might broadly influence the results of the differences by city, especially in preferences for shared bus lanes and shared pedestrian paths. There are more male cyclists and a preference for shared bus lanes in Leeds while there are more female cyclists and a higher preference for shared pedestrian paths and off-roads in York.

4.7 Differences in Preferences to Route Factors by Confidence level

In this section the analysis results of the differences of attitudes by the confidence level are presented.

As with the previous sections, key findings are at first described with interpretations about the meanings of the findings before then moving onto a discussion of them.

All the tables in this section show mean values. Statistically significant variables are summarised in tables, so full statistical results are provided in Appendix 4-3.

4.7.1 Importance on Road and Traffic Factors

Figure 4-4 shows ranks of the factors in importance by the groups by confidence level. Overall, traffic related factors and cycling facility were ranked at higher places. However, the detailed ranks of individual factors varied by groups.

Traffic speed and icy surfaces in winter were ranked as the most important two factors except for respondents at the beginner level, for whom icy surfaces in winter were located at 4th place. Traffic speed was the most important factor for the respondents at the beginner and unconfident levels, while icy surfaces were the most important factor for the respondents at the confident and very confident levels. When considering that icy surfaces are usually a season factor, traffic speed was the most important factor overall.

The reason that icy surfaces in winter did not place at a high place in *Beginner* would be because beginner cyclists may not cycle under such poor weather conditions. Although there was not much studying of the relationship between icy surface or winter and confidence level or the experience of cyclists, cycling during winter decreases in frequency and distance (Stinson and Bhat 2004; Guo et al., 2007; Bergström and Magnussen, 2003). So it is highly possible that cyclists at beginner level stop cycling or at least do not cycle when surface is icy and frozen.

The most dramatic differences were found with traffic volume. The importance of traffic volume was dropped from the 2nd place for *Beginner* to 10th place for *Very Confident*. Even the scores also significantly decreased to 3.98 for *Very Confident*, which is below a median score of 4.

	Beginner		Unconfident		Confident		Very confident	
	Traffic speed	6.27	Traffic speed	5.92	Icy surface	5.51	Icy surface	5.44
	Traffic volume	5.78	Icy surface	5.71	Traffic speed	5.41	Traffic speed	4.65
	Lane width	5.76	Off-road path	5.39	HGVs	4.95	Cycling facility	4.32
	Icy surface	5.72	Cycling facility	5.39	Lane width	4.90	Off-road path	4.30
	Off-road path	5.69	Traffic volume	5.36	Cycling facility	4.89	Lane width	4.23
	Cycling facility	5.67	HGVs	5.33	Off-road path	4.84	Surface	4.22
	HGVs	5.53	Lane width	5.27	Traffic volume	4.80	HGVs	4.17
	Security	5.39	Security	5.02	Security	4.44	Scenery	4.09
Above 5.0	Lighting/Darkness	5.05	Buses	4.54	Buses	4.39	Security	4.08
Below	Traffic calming	4.81	Scenery	4.36	Scenery	4.27	Traffic volume	3.98
	Buses	4.77	Surface	4.30	Surface	4.25	Buses	3.70
	Surface	4.42	Traffic calming	4.22	Lighting/Darkness	3.98	Traffic calming	3.66
Above 4.0	Scenery	4.14	Lighting/Darkness	4.19	Traffic calming	3.91	Lighting/Darkness	3.66
Below	Gradient	3.86	Gradient	3.87	Gradient	3.88	Gradient	3.52
	Parked vehicles	3.73	Parked vehicles	3.85	Parked vehicles	3.61	Parked vehicles	3.31

Figure 4.4 Ranks of Importance of Road and Traffic Factors for Route Choice by Confidence Level

The different patterns between traffic speed and volume indicate that major risks from traffic are caused by moving vehicles at high speed. This is clearer with the fact that parked vehicles were placed as the least important factors regardless of the levels. However, when cyclists are unconfident when cycling with vehicles, just the presence of vehicles is also a serious concern. The importance of traffic volume at a low level is unrealistic, and maybe the values are overestimated values due to the lack of confidence.

Cycling facility and off-roads were importantly considered through all the levels. Interestingly they moved together in the changes of ranks with slight differences in order of confidence levels. At the *Beginner* and *Unconfident* levels, off-road paths were more important, while cycling facilities were more important for the *Confiden*t and *Very Confident* levels. The differences in the scores were very small, so it cannot be said that there are real differences.

Beginner especially placed lane width at a high place (3rd) while it was relatively low in the rank for the other groups. The reason may be that wider space on lanes gives cyclists a little leeway from vehicles. Although it is physically a little difference, cyclists at the *Beginner* level might think it is important.

Although surface quality and scenery are not important factors according to the scores, their pattern in the ranks is interesting. They were placed in the low ranks for *Beginner* and then went up slightly to higher places for *Unconfident* and *Confident*. The two factors then went up further for *Very Confident*. Cyclists at that level considered the factors more importantly than security, traffic volume or buses. This indicates that most of the factors are not really matters for cycling and route choices for cyclists at the *Very Confident* level and they pay more interest to more enjoyable features such as good scenery and smooth surfaces for riding. With this, attitudes of the cyclists at *Very Confident* are distinguishable from the other groups.

4.7.2 Differences in Attitudes for Route Factors

Table 4.29 shows a summary of differences via the confidence levels about the factors for route choices. Development of confidence clearly influenced preferences and behaviours as well as feeling unsafe from route features.

Overall, there were significant differences between *Beginner* and *Very Confident. T*he patterns of the differences in preferences were more likely grouped into two groups rather than 4. *Beginner* and *Unconfident* showed

Table 4.29 Differences in the Attitudes by Confidence Level

Likelihood to choose	Beginner	Unconfident	Confident	Very Confident
Road and traffic circumstance				
High traffic speed	2.28[3,4]	2.48[3,4]	3.28[1,2,4]	4.21[1,2,3]
Frequently running HGVs	2.62[3,4]	2.85[3,4]	3.63[1,2,4]	4.40[1,2,3]
Large traffic volume	2.75[3,4]	3.45[3,4]	4.15[1,2,4]	4.93[1,2,3]
Poor personal or area security	2.84[3,4]	3.01[4]	3.54[1,4]	4.32[1,2,3]
Poor street lighting in dark	3.03[3,4]	3.69[4]	4.12[1,4]	4.67[1,2,3]
Icy surface in winter	2.21[3,4]	2.29[4]	2.75[1]	3.20[1,2]
Frequently running buses	3.76[3,4]	4.41[4]	4.89[1]	5.29[1,2]
Steep uphill	4.02[3,4]	4.58[4]	4.76[1,4]	5.48[1,2,3]
Narrow space on lane	4.25[4]	4.26[4]	4.63[4]	5.53[1,2,3]
Steep downhill	4.92[4]	5.11[4]	5.35[4]	5.87[1,2,3]
Poor surface	3.65[4]	3.29[3,4]	3.92[2]	4.47[1,2]
Parked vehicles on street	4.36[4]	4.65[4]	4.89[4]	5.50[1,2,3]
Moderate uphill	5.25[4]	5.47[4]	5.56[4]	6.12[1,2,3]
Cycling facility				
Cycle lane	6.59[3,4]	6.45	6.19[1]	5.96[1]
Off-road path	6.52[3,4]	6.09	5.76[1]	5.66[1]
Bridge with a cycling only facility	6.30[3,4]	5.75	5.44[1]	5.51[1]
On-road cycle lane	4.68[3,4]	5.18	5.29[1]	5.43[1]
Shared bus lane	3.52[3,4]	4.34[4]	4.71[1]	5.05[1,2]
Junctions				
Behaviour				
Avoid roundabouts	4.77[3,4]	3.86[3,4]	3.05[1,2,4]	2.37[1,2,3]
Avoid junctions frequently used by vehicles	4.47[3,4]	3.62[3,4]	2.66[1,2,4]	2.09[1,2,3]
Avoid junctions for right turn	4.38[3,4]	3.63[3,4]	2.64[1,2,4]	2.17[1,2,3]
Avoid signalised junctions	3.13[3,4]	2.42[4]	2.26[1,4]	1.94[1,2,3]
Avoid give-way junctions	3.37[3,4]	2.55[4]	2.22[1]	2.02[1,2]
Importance of feature				
Complexity	5.41[3,4]	5.21[4]	4.75[1,4]	3.56[1,2,3]
Size	5.02[3,4]	4.55[4]	4.17[1,4]	3.41[1,2,3]
Number of vehicles making turn	5.28[3,4]	4.70[4]	4.18[1,4]	3.11[1,2,3]
Advanced stop line	5.03[4]	4.47[4]	4.32[4]	3.39[1,2,3]
Feeling unsafe				
High traffic speed	6.75[2,3,4]	6.32[1,3,4]	5.83[1,2,4]	5.08[1,2,3]
HGVs or buses	6.38[2,3,4]	5.93[1,3,4]	5.46[1,2,4]	4.67[1,2,3]
Large traffic volume	6.23[2,3,4]	5.39[1,3,4]	4.88[1,2,4]	4.16[1,2,3]
Changing lane in traffic	5.56[3,4]	4.99[3,4]	4.30[1,2,4]	3.38[1,2,3]
Making right turn at junction	5.29[3,4]	4.77[3,4]	4.04[1,2,4]	3.39[1,2,3]
Environment of areas nearby route	4.87[3,4]	4.57[3,4]	4.05[1,2,4]	3.41[1,2,3]
Not enough distance from vehicles	6.48[3,4]	6.04[4]	5.73[1,4]	5.06[1,2,3]
Riding on roads in poor weather	6.14[3,4]	5.66[4]	5.52[1,4]	4.98[1,2,3]

Items in superscript indicate which means are significantly different from each other (Kruskal-Wallis Multiple comparisons)

similar preferences while *Confident* and *Very Confident* were similar to each other. However, despite no differences in the attitudes between *Beginner* and *Unconfident*, there were differences in a few factors between *Confident* and *Very Confident*.

More details are presented in the following sections.

4.7.2.1 Preference on Road and Traffic Factors and Cycling Facility

Respondents at the *Beginner* level far less preferred most of the factors related with traffic and road, while more preferred most of the cycling facilities except for on-road cycle lanes and shared bus lanes. Most of the factors had a significant difference between *Beginner or Unconfident* and *Very Confident* and some between *Confident* and *Very Confident*.

Development of confidence level most significantly influenced 3 traffic related factors: high traffic speed, large traffic volume and HGVs. The three factors had differences in preference between *Beginner/Unconfident, Confident,* and *Very confident*. Poor security and poor lighting were also significantly less preferred by cyclists at the *Beginner* level than cyclists at the *Confident* or *Very Unconfident* levels. These results indicates that there are the large gaps in the attitudes to traffic related issues and personal security between *Beginner/Unconfident* and *Very confident/ Confident*.

Cyclists at the *Very Confident* level were exceptionally less sensitive to most of the factors, so they did not much care about road and traffic conditions. This means that this type of cyclists will cycle whatever the route conditions are, good or bad.

Cyclists at the beginner level were not likely to choose the factors with poor conditions. Only a limited number of the factors were over a score of 4, including hilliness, parked vehicles on streets and narrow space on road lanes. Interestingly narrow space on lanes was preferred. This finding is rather inconsistent with the finding from feeling unsafe. However, this may be because most residential and local streets are narrow. From the cyclists' point of view, narrow space on lanes does not always mean very difficult conditions for cycling. These factors were also significantly preferred by the *Very Confident.* They were also more related with convenience for cycling rather than risks. Therefore the cyclists at the *Very Confident* level seem to not much care about the route conditions unless they are critical for their safety. In other words, these factors will have little influence on the choices of *Very Confident* with improvement of the condition.

In terms of cycling facility, significant differences in preference existed between the *Beginner* and *Very Confident or Confident*. Cyclists at the *Beginner* level more preferred most of cycling facilities than cyclists at *Confident or Very Confident* levels (Stinson and Bhat, 2005; Hunt and Abraham, 2007). However, on-road cycle lanes and shared bus lanes were less preferred by the *Beginner* group. Shared bus lanes were less preferred, even by *Unconfident*. The low score of shared bus lanes (3.52) reflects fear of buses by cyclists at beginner levels, while cyclists at confident or very confident levels actually welcome using bus lanes. These results indicate that the cyclists at the *Beginner* level were very sensitive to whether or not a cycling facility separates cyclists from traffic. The facilities which do not separate cyclists from traffic were less preferred by beginner cyclists than by more confident ones.

4.7.2.2 Attitudes towards Junctions

Patterns of difference in the attitudes towards junctions were similar to the patterns in road and traffic factors. Beginner cyclists tended to avoid junctions more. The three behaviours: avoiding roundabouts, avoiding junctions frequently used by vehicles and avoiding junctions for right turn were especially meaningful as they were the only behaviours which had the score of over 4.0 and only by the *Beginner* group. This indicates that roundabouts, making a right turn at a junction and interactions with vehicles at junctions are still problems, at least for the beginner cyclists, whereas signalised junctions and give-way junctions provide a more comfortable environment for crossing a junction, especially a signalised one. It is obvious, as less confident cyclists are less good at paying attention to approaching vehicles and signalised junctions provide clear phases for whether or not to go or stop. Usually give-way junctions are easy to cross as they are installed at a small intersection with a small amount of traffic in residential roads.

In terms of importance of junction features, respondents chose complexity of a junction as the most important feature regardless of the confidence levels, whereas the other features are rather unstable. However, *Beginner* and *Unconfident* placed a number of vehicles making a right turn in 2nd place. This means that making a right turn with many vehicles is a burden for less confident cyclists. A more important point is that cyclists at the *Beginne*r level gave a relatively high score to all the features. Therefore, not only is making a right turn an issue, but also crossing a junction itself is a difficult task for cyclists at a beginner level (Stinson and Bhat, 2005, Sener et al., 2009).

4.7.2.3 Feeling Unsafe from Route Features

The results indicates that high traffic speed and not enough distance from vehicles and HGVs are the most risky factors regardless of confidence levels. Icy surface is another risk factor, but in winter only.

Development of confidence level significantly influenced feeling unsafe about route factors (Stinson and Bhat, 2005). The number of the factors with which cyclists feel unsafe significantly decreased with the increase of confidence level of cyclists from 13 out of 16 factors for the *Beginner* level to 8 factors for the *Very Confident* level (see Appendix 4-3). The scores for the individual factors also dropped significantly with the development of confidence level.

The confidence levels more strongly and broadly influenced the change of feeling unsafe about the factors than preference. There were significant differences between all the levels with three factors: high traffic speed, HGVs and buses and large traffic volume. There were also significant differences between *Very Confident, Confident* and *Beginner* or *Unconfident* with several other factors.

The results clearly provide the signal that making away from vehicles is the best way to make cyclists feel safe on roads regardless of confidence levels. Furthermore, there is a large gap in feeling risky between *Beginner* cyclists (including *Unconfident* cyclists) and *Confident* ones.

4.7.3 Discussion in Differences by Confidence Level

Cyclists at the *Beginner* level were far more sensitive to most of the factors than cyclists at the *Very Confident* one. However, the analysis also found that the key factors which reflect the characteristic of each confidence level. This section focuses on 4 key findings for further discussion.

The key is separation from vehicles

The most important finding is that beginner cyclists are very sensitive to the presence of moving vehicles and separation from vehicles. The factors which were not preferred by cyclists were also the factors which made cyclists feel unsafe. The relationship between traffic related factors and feeling unsafe was clearly in correlation. Meanwhile, the preference about cycling facilities indicated that less confident cyclists far less preferred the facilities which do not separate cyclists from vehicles than more confident cyclists. This could be because less confident cyclists feel extremely unsafe when cycling with vehicles. As a consequence, less confident cyclists avoid situations in which they cycle side by side with vehicles and prefer cycling facilities which allow proper space separating them Even less confident cyclists did not feel unsafe with and did not dislike parked vehicles. Parked vehicles have a limited influence on safety (Stinson and Bhat, 2005) So moving vehicles rather than parked vehicles are a matter for them. This tendency is far stronger with cyclists at the beginner level.

This does not mean that confident cyclists like riding in mixed traffic; they are just less sensitive to traffic and riding with vehicles (Hunt and Abraham, 2007) as increased confidence tends to reduce the fear from traffic and to make cyclists more skilful and comfortable at riding with vehicles.

Traffic volume; the tricky factor

Traffic volume is a rather tricky factor. It is obvious from the results that cyclists at beginner levels more importantly consider traffic volume (Dill and Gliebe, 2008), but the importance soon drops as confidence increases (Sener et al., 2009). So it raises the question of whether traffic volume is really a matter.

Traffic volume can be a problem when it is combined with other factors; for example a large number of right turning vehicles at a junction, not enough rooms for changing a lane due to packed vehicles, or with buses.

On the other hand, a different view about traffic volume exists. Large traffic does not always mean a large number of fast moving cars, but sometimes it means a large number of slow moving cars. Under such a situation, there will be not much of a problem regarding safety, but there is inefficiency in moving through. Confident cyclists can probably easily find room for manoeuvring while unconfident cyclists cannot find proper rooms for passing through. The problem could be more inconvenient for unconfident cyclists, so from their point of view traffic volume is a problem for both safety and convenience, as well as safety due to lack of confidence and experience.

Why no difference between Beginner and Unconfident?

The results revealed that there was not much difference in the attitudes regarding route choices between *Beginner* and *Unconfident*. The study by Hunt and Abraham (2007) also divided samples into 4 experience levels and

4 comfort levels. In the study, highly inexperienced or highly uncomfortable cyclists showed somewhat odd patterns in preferences. The authors explained that this might be because of the small sample size, which was 31. In contrast, the problem with this study is that there is little difference in preferences but there were differences in importance of road and traffic factors for route choices. One explanation could be that there is actually no difference between beginner cyclists and unconfident ones. They are both not confident enough to distinguish themselves in preference, so merging beginner cyclists and unconfident cyclists is rational. Only with the results of the study does segmenting cyclists in 3 confidence levels seem more rational. However, as very few studies have been conducted about detailed segmentation for confidence, it would be too early to make a conclusion.

On the other side, as there were clear differences in the importance of road and traffic factors, it can be assumed that a real matter with route choice is not preference about good or bad conditions of each potential factor, but rather priority of the factors. Even though the condition of a certain factor is good and highly preferred, if the factor is a low priority it may not be chosen. Furthermore, although it is not statistically significant, the *Beginner* and *Unconfident* groups had differences in preference in the right way; for example beginner cyclists preferred routes with bad condition less than routes with good conditions. Therefore the latter explanation seems to be more rational.

Very confident or too confident

Very confident cyclists are clearly distinguishable from the other groups. They were significantly less sensitive to most of the factors regardless of preference or feeling unsafe. Although several factors such as cycling facilities and off-road paths had a score of over 4.0, the scores of most of the factors given by very confident cyclists were close to a score of 4.0. Therefore, strictly speaking, only traffic speed and icy surface were actually important for route choice. The other factors were a matter of convenience, at least for very confident cyclists. This may be supported by the idea that surface quality and scenery were placed at higher ranks than the other groups.

The problem is that highly confident cyclists tended to experience higher accident rates in serious accidents and slight accidents with treatment (see Table 4.13). So it can be assumed that very confident cyclists seem to be rather over-confident at cycling or tend to take risks more than unconfident ones (Stinson and Bhat, 2005). They will be less cautious and careful in cycling. Therefore, proper reminders for safety in cycling are required for confident cyclists as well as unconfident ones.

4.8 Differences in Preferences for Route Factors by Criteria based Cyclist Types

This section presents differences in the attitudes to route factors by criteria based cyclist types, which are described in section 4.3.3.2.

As with the previous sections, key findings are at first described with interpretations about the meanings of the findings before then moving towards discussion.

All the tables in this section show mean values. Statistically significant variables are summarised in tables, so full statistical results are provided in Appendix 4-4.

4.8.1 Importance on Road and Traffic Factors

Figure 4.5 shows priorities in importance of the factors for route choices by the groups based on route choice criteria. Overall, traffic related factors and cycling facilities were ranked at higher places while the factors which are not directly related to traffic, such as scenery and hilliness, were placed at a lower priority. The results confirm that traffic and cycling facilities are more important than the other factors for route choices, and these results are consistent with the findings from the previous sections.

Although all the types mostly agreed that traffic speed and icy surface in winter were more important than the other factors, the characteristics of each types were reflected in the factors after the 3rd place. Lane width was the 2nd important factor for *Worried Cyclists* while cycling facilities were located in 3rd place for *Heavenly* and *Speedy Cyclists*. Off-roads were the 3rd important factor for *NTI Cyclists*.

Worried Cyclists may put lane width at 2nd so that they have space from vehicles to secure safe riding. Lane width, especially wide space, is important from their point of view and cycling facility is also important as they provide separation from vehicles.

Heavenly Cyclists and *Speedy Cyclists* both put cycling facilities in 3rd place. However, the reasons seems different. *Heavenly Cyclists* probably consider

	Heavenly		*Worried*		*Speedy*		*NTI*	
	Traffic speed	6.23	Traffic speed	6.06	Icy surface	5.57	Icy surface	5.15
	Icy surface	5.99	Lane width	5.80	Traffic speed	5.37	Traffic speed	4.84
	Cycling facility	5.71	Icy surface	5.75	Cycling facility	5.05	Off-road path	4.33
	Traffic volume	5.66	Cycling facility	5.75	Lane width	4.91	HGVs	4.28
	Lane width	5.63	HGVs	5.73	Off-road path	4.82	Traffic volume	4.15
	Off-road path	5.57	Off-road path	5.58	HGVs	4.79	Lane width	4.05
	HGVs	5.54	Traffic volume	5.53	Traffic volume	4.74	Cycling facility	4.04
Above 5.0	Security	5.47	Security	5.02	Security	4.48	Security	3.94
Below	Bus	4.99	Bus	4.82	Surface	4.42	Scenery	3.90
	Scenery	4.87	Scenery	4.73	Bus	4.30	Surface	3.76
	Traffic calming	4.83	Traffic calming	4.66	Lighting/Darkness	4.17	Bus	3.57
	Surface	4.79	Lighting/Darkness	4.48	Traffic calming	3.94	Lighting/Darkness	3.41
	Lighting/Darkness	4.65	Surface	4.42	Gradient	3.89	Traffic calming	3.26
	Gradient	4.49	Parked vehicles	4.15	Scenery	3.83	Gradient	3.20
Above 4.0	Parked vehicles	4.02	Gradient	3.85	Parked vehicles	3.57	Parked vehicles	3.10
Below								

Figure 4.5 Ranks of Importance of Road and Traffic Factors for Route Choice by Criteria based Cyclist Types

cycling facilities important as they can benefit from both safe and quick trips at the same time while *Speedy Cyclists* focus more on quick trips. These assumptions do not have any evidence yet, but considering the characteristics of each type, they are fairly realistic.

NTI Cyclists placed put off-roads at 3rd. This is probably because of the benefits of off-roads, which do not have junctions. *NTI Cyclists* extremely dislike junctions, so they like using off-roads if possible, and the rank of cycling facilities was fairly low for them. This is also due to the similar reason that they like off-roads. Routes with cycling facilities also have junctions in most cases, so these facilities are relatively less important for them.

Among the factors in the relatively less important group, scenery is identical with *Speedy Cyclists,* coming in surprisingly low. This clearly shows that the main interest of this type for cycling routes is making a quick trip.

The factor of security had a certain role, as it divided all the factors into two groups: a more important group and less important group for each type. It probably indicates that security is a kind of guideline for route choices, which is also related with safety as well. The factors below security are relatively not much related with core demands for routes from the cyclists' point of view. This is fairly supported by the similar patterns from the previous results.

4.8.2 Differences in Attitudes to Route Factors

Table 4.30 shows a summary of differences in the attitudes to the factors for route choices by criteria based cyclist types.

Overall, it was rather difficult to find regular patterns regarding the cyclist types. However, the types were divided into 2 groups: *Heavenly/Worried* cyclists and *Speedy/NTI* cyclists in the patterns of difference in preference, especially with cycling facilities and junctions. On the other hand, there was little difference in the attitudes between *Heavenly* and *Worried* cyclists and between *Speedy* and *NTI* cyclists.

Table 4.30 Differences in the Attitudes by Criteria based Cyclist Types

Likelihood to choose	*Heavenly*	*Worried*	*Speedy*	*NTI*
Road and traffic circumstance				
Large traffic volume	3.83	3.26[3,4]	4.20[2]	4.19[2]
High traffic speed	2.97	2.52[3,4]	3.33[2]	3.47[2]
Frequently running HGVs	3.29[2]	2.69[1,3,4]	4.93[2]	4.68[2]
Frequently running buses	4.60	4.18[3]	4.93[2]	4.68
Traffic calming	5.81[3,4]	5.50	5.22[1]	5.06[1]
Poor personal or area security	3.42	3.04[4]	3.58	3.80[2]
Wide space on lane	6.57[3,4]	6.35	6.14[1]	5.94[1]
Moderate downhill	6.30[2,3,4]	5.85[1]	5.76[1]	5.76[1]
Steep uphill	4.84	4.72	4.47[4]	5.02[3]
Moderate uphill	5.92[3]	5.53	5.47[1]	5.58
Good scenery	5.65[3]	5.63[3]	4.99[1,2]	5.31
Cycling facility				
Cycle lane	6.57 [3,4]	6.67 [3,4]	6.20 [1,2]	5.92 [1,2]
Segregated cycle path	6.54 [3,4]	6.66 [3,4]	6.05 [1,2]	5.71 [1,2]
Off-road path	6.33 [3,4]	6.48 [3,4]	5.75 [1,2]	5.58 [1,2]
Cycle crossing facility	6.19 [3,4]	6.01 [3,4]	5.23 [1,2]	4.62 [1,2]
Bridge with a cycling only facility	6.33 [3,4]	5.93 [3,4]	5.39 [1,2]	5.20 [1,2]
Advanced stop line	6.24 [4]	6.12 [4]	5.83 [4]	5.30 [1,2,3]
Shared pedestrian path	5.29 [3,4]	5.13 [4]	4.66 [1]	4.04 [2,1]
Junctions				
Behaviour				
Avoid roundabout	3.72 [4]	3.96 [4]	3.25	2.67 [1,2]
Avoid give-way junction	2.89 [4]	2.70 [4]	2.37 [4]	1.86 [1,2,3]
Avoid signalised junction	2.71 [4]	2.46 [4]	2.37 [4]	1.90 [1,2,3]
Avoid junction frequently used by vehicles	3.72 [3,4]	3.73 [3,4]	2.79 [1,2]	2.29 [1,2]
Avoid junction for right turn	3.62 [3,4]	3.61 [3,4]	2.79 [1,2]	2.35 [1,2]
Importance of feature				
Complexity	5.25 [3,4]	5.25[3,4]	4.66 [1,2]	4.00 [1,2]
Size	5.01 [3,4]	4.75 [3,4]	4.00 [1,2]	3.60 [1,2]
Number of vehicles making turn	4.97 [3,4]	4.89 [3,4]	4.11 [1,2]	3.51 [1,2]
Advanced stop line	4.97 [3,4]	5.29 [3,4]	4.17 [1,2,4]	3.14 [1,2,3]
Feeling unsafe				
High traffic speed	6.21 [4]	6.34 [3,4]	5.90 [2]	5.52 [1,2]
HGVs or buses	5.75 [4]	5.89 [3,4]	5.52 [2]	5.17 [1,2]
Riding without proper lights in dark	5.48 [4]	5.22	5.25	4.82 [1]
Large traffic volume	5.48 [3,4]	5.61 [3,4]	5.02 [2,4,1]	4.46 [1,2,3]
Changing lane in traffic	4.58 [4]	4.92 [4]	4.46	3.95 [1,2]
Making right turn at junction	4.45 [4]	4.77 [3,4]	4.19 [2]	3.83 [1,2]
Environment of areas nearby route	4.70 [4]	4.16	4.17	3.75 [1]
Not enough distance from vehicles	6.11 [3,4]	5.96	5.74 [1]	5.42 [1]
Vehicles parked on street	4.54 [3]	4.40	4.04 [1]	3.95
Steep downhill	3.57 [4]	3.34 [4]	3.24 [4]	2.68 [1,2,3]
Steep uphill	3.30 [4]	2.86	3.09 [4]	2.41 [1,3]

Items in superscript indicate which means are significantly different from each other (Kruskal-Wallis Multiple comparisons)

4.8.2.1 Preference for Road and Traffic Factors and Cycling Facility

Worried Cyclists less preferred routes with high traffic speed, large traffic volume and frequently running HGVs than *Speedy* and *NTI* cyclists. In addition, *Worried Cyclists* also less preferred routes with poor security than *NTI* ones. *Worried Cyclists* were also more sensitive to the factors which increase risks along routes.

On the other hand, *Heavenly Cyclists* preferred routes with traffic calming, moderate uphill and downhill slopes, good scenery and wide space on lanes more than *Speedy* and *NTI Cyclists*. Several factors which are less critical for safety of routes were highly preferred by *Heavenly Cyclists*. This is explained by the characteristics of *Heavenly Cyclists*, who expect all of potential conditions of a route to be good.

There were noticeable differences with several factors with *Speedy Cyclists*, as they preferred routes with large traffic volume and frequent HGV or bus running and disliked routes with moderate and steep uphills and good scenery. The reason for the former could be because it is beneficial for saving trip time to ride on roads with such conditions, while the reason for the latter could be because such conditions can reduce trip speed and increase trip time. So all of the factors are related with saving time except for good scenery, which has no influence in trip itself, so it is out of interest for *Speedy Cyclists*.

In terms of cycling facilities, preferences were clearly divided into two groups: group of *Heavenly Cyclists* and *Worried Cyclists* and a group of *Speedy Cyclists* and *NTI Cyclists*. There was no statistical significance between *Heavenly* and *Worried* cyclists and between *Speedy* and *NTI* cyclists. *Heavenly/Worried* types preferred using cycling facilities regardless of the type more than the *Speedy/NTI* cyclists. This is mainly because they believe that cycling facilities reduce risks from vehicles. Therefore cycling facilities are more beneficial in providing a safer environment than a quick trip to a destination.

4.8.2.2 Attitudes towards Junctions

Junctions are not important factor for *NTI Cyclists*; however, that does not mean that they avoid junctions. The results shows that *NTI Cyclists* avoided junctions the leas, so they are simply a bothersome infrastructure on roads for their riding.

As shown in Table 4.30, cyclists in general did not try avoiding junctions regardless of the types and their conditions. However, junctions were a little more hazardous a feature on routes for more safety concerned cyclists. *Heavenly* and *Worried* cyclists tended to more avoid junctions more than *Speedy* and *NTI* cyclists.

In terms of importance of the junction features, *Heavenly Cyclists* and *Worried Cyclists* more importantly took all the features into account than their *Speedy* and *NTI* cyclists. An advanced stop line was the most important factor for route choice for *Worried Cyclists* unlike the others. It may indicate that an advanced stop line is a large advantage for cyclists in terms of safety, as it clearly provides rooms for cyclists in front of vehicles. Drivers can recognise that there are cyclists there (Dill et al., 2012) and will start moving after they move.

4.8.2.3 Feeling Unsafe from Route Features

Overall, *Heavenly Cyclists* felt more unsafe with most of the route factors than *NTI Cyclists,* while *Worried Cyclists* felt more unsafe than *Speedy* or *NTI* ones with a limited number of the factors, including high traffic speed, large traffic volume, changing a lane in traffic and making a right turn at a junction. On the other hand, there was no difference between *Speedy Cyclists* and *NTI Cyclists* except for large traffic volume, with which S*peedy Cyclists* felt more unsafe.

It is rather difficult to derive any clear findings from the results. Some factors were regarded as more unsafe by *Worried Cyclists* while some were by the *Heavenly*. Although initial expectation from the analysis was that *Worried Cyclists* felt more unsafe with the factors than even *Heavenly* ones, the results were different from the expectation. The factors for which *Worried Cyclists* had higher scores than *Heavenly Cyclists* included interaction with traffic, traffic speed, HGVs and buses, traffic volume, changing a lane in traffic and making a right turn at a junction. On the other hand, the factors for which *Heavenly* had higher scores were less related with traffic, such as security and lighting, except for the lack of distance from vehicles. It seems that *Heavenly Cyclists* pay more attention to non-traffic related factors than *Worried Cyclists.* In another aspect, it says that traffic is more a core source that cyclists feel risky from. However, not enough distance from vehicles is an unexpected result. The results of the importance rank of road and traffic factors said that *Worried Cyclists* thought land width was more important than any other factors, except for traffic speed, so these two results are rather inconsistent.

4.8.3 Discussion in Differences by Criteria based Cyclist Types

In this section 3 topics are discussed: meanings of the segments based on route choice criteria. advanced stop lines and land width in order.

Characteristics of criteria based cyclists

The analysis results shows that the 4 segments defined with route choice criteria do not clearly distinguish each other. The patterns in the attitudes of each type were more like two groups. *Speedy Cyclists* and *NTI Cyclists* were very similar, while *Heavenly Cyclists* and *Worried Cyclists* also shared similarities to each other.

NTI Cyclists are quite extreme. Although their key characteristic is negative attitudes to junctions, they showed clearly less sensitiveness to all the factors. They can cycle regardless of the presence of cycling facilities (Dill and McNeil, 2012). Furthermore, they do not much care about route conditions. In the point of policies, they are hardly affected by improvement of the route environment.

Speedy Cyclists are confident and good at cycling with most conditions on the road, but they also prefer using cycling facilities for making a quick trip. The majority of commuter cyclists belong to this type. There aren't exactly matching types from previous studies, but *Speedy Cyclists* were partially similar to *Dedicated Cyclists* in the study of Damant-Sirois et al. (2013) and are partially similar to *Enthused and Confident* in the study of Dill and McNeil (2012). However, *Speedy Cyclists* more prefer using cycling facilities than *Dedicated Cyclists*, while they are more comfortable without cycling facilities on roads than *Enthused and Confident* types. The importance of this type is that they are actually typical commuter cyclists, more focused commuting or utility cycling than the other kinds. Their demands will be more specific to commuting and utility purposes, so improvement of the cycling environment for transport purposes will highly satisfy them (for example, they will much more welcome expanding bus lanes).

On the other hand, *Worried Cyclists* were similar to *Path-using Cyclists* in the study by Damant-Sirois et al. (2013). Both types prefer using cycling facilities and separation from vehicles. However, *Path-using Cyclists* were more like easy-going cyclists as convenience and fun were their main motivations for cycling (Damant-Sirois et al., 2013). Both *Worried Cyclists* and *Path-using Cyclists* demand risk free networks and will get positively impacted by improvement of infrastructure.

Heavenly Cyclists are similar to *Worried Cyclists.* They were more generous towards the poor conditions of cycling routes than *Worried Cyclists* but they more sensitive to security and convenience, such as surface quality and lightings. Therefore overall demands for the conditions of cycling routes are high, and this type will be similar to non-cyclists, who just have somewhat idealistic images for cycling and their expectations for cycling routes in mind.

As a consequence, the demands and expectations of *Worried Cyclists* and *Speedy Cyclists* are standard guides for developing policies and strategies for cycling and relevant infrastructures. *Heavenly Cyclists* can become a reference for further considerations.

Advanced stop lines

It was noticeable that *Worried Cyclists* considered advance stop lines as the most important factor among junction features. The benefit of advanced stop lines is to increase awareness of drivers about the potential presence of cyclists there (Dill et al. 2012). Although this study did not try to probe extensively about advanced stop lines, the results indicate that the cyclists who have more concern about safety have a very positive attitude towards advanced stop lines, as they improve safety, maybe just perceived safety (Newman, 2002; Rodgers, 2005; Wall et al. 2003).

Through the analysis of the questionnaire part of the study, advanced stop lines were more favoured by certain types of cyclists. Advanced stop lines were significantly more important to *Worried Cyclists* and female cyclists (see Table 4.26). Several studies also found that not all cyclists used advanced stop lines appropriately (Allen et al., 2005; Atkins Service, 2005; Hunter, 2000; Wall et al., 2003). Therefore the variations in preference about advanced stop lines are natural as shown in this study. Despite this limitation, advanced stop lines can be very effective measures for improving safety for female cyclists and the cyclists who value safety highly.

Lane width for safety

Worried cyclists highly ranked lane width in the importance of the factors for consideration of route choices. This means that at least cyclists who are more interested in safety of routes think that lane width is an important factor for securing their safety from vehicles on roads. This is consistent with the findings from the segments by confidence level in which beginner cyclists more importantly considered land width.

Few studies been done about lane width, but Hopkinson and Wardman (1996) found that cyclists preferred wider lanes, even with extra 10 minutes for a trip than standard lanes. Parkin et al. (2007) also found that cycling routes with parking were more risky than without parking. Although the presence of parking does not directly mean lane width, the presence of on-street parking will be similar to narrowing lane width.

It is obvious that certain cyclists feel more danger from approaching vehicles, and narrow distances increase the fear. The preference for wider lanes can be found with all cyclists; however, wider lanes are just optional for some but compulsory for others. Preference towards cycle lanes or segregated cycle paths is also the same reason behind the preference for wider lanes. Therefore it is important to provide enough distance from vehicles either through wider lanes or cycling facility.

4.9 Conclusions of the Chapter

It is actually difficult to justify what cyclists should be targeted with and what measures for cycling policies and strategies should be used. Not many studies have been done to probe the various characteristics and demands of cyclists. This study provided an overall hierarchy of and preference in the factors for route choices and differences by the characteristics of cyclists. It also provided typologies using confidence level and route choice criteria. Overall, it concluded that traffic related factors are more important in consideration of route choices and that they are correlated with safety. In detail, there are variations by the characteristics of cyclists. The characteristics of cyclists mainly influence the order of importance of the route factors, the degree of preferences for the factors and of feeling unsafe from the factors.

The study proved that safety, preference and importance of the route factors are strongly related to each other. All the factors which were more important for route choice were traffic or security-related factors and cycling facilities. The other factors, such as hilliness or scenery, were less important, and they were the factors for things like convenience. The only exception was icy surfaces, which increased the possibility of accidents in winter.

The analysis clearly proved that importance of cycling facilities and potential risks in traffic. There are relationships among traffic, safety and cycling facilities. As shown in Figure 4.3, cycling facilities and traffic related factors are located opposite each other. In addition to the locations of these factors, traffic related factors were highly correlated with perceived risk. Therefore the key role of a cycling facility is to remedy risks from traffic related factors.

There were clear differences between male and female cyclists in terms of preference for the route factors. However, these differences do not mean female cyclists stand on a completely opposite site. Female cyclists paid more attention to safety matters than males. The concern of female cyclists about safety made them think more about off-road paths, lane width, security, and lightings and prefer cycling facilities than male cyclists. These differences are also related with the lack in confidence with female cyclists and cycling with traffic.

In the aspects of cycling policies, targeting females and designing and providing facilities that fit the expectations of female cyclists is a better strategy for planning better cycling routes as well as promoting cycling. Female cyclists are less active in cycling and worry more about safety. Women are a weaker and disadvantaged target, making women cyclists more comfortable is an important task for the increase in cycling uses for transport purposes. York has more female cyclists and they cycles more for utility purposes. Having a more friendly environment for cycling probably means providing a better environment for female cyclists.

The differences between Leeds and York reflect the cycling environment that each city has. Leeds is a kind of car-oriented city, so cyclists there are rather forced to negotiate the car-oriented environment and have become more tolerant to high traffic speed or bus lanes. On the other hand, York is a tourist city always with lots of pedestrians and has a better cycling environment. The off-roads along the river passing through the central area of York are a good network for cycling. Such an environment influenced more of a positive attitude to off-roads and a negative attitude to bus lanes. Cyclists in York also preferred shared pedestrian paths than cyclists in Leeds.

The patterns of the attitudes of cyclists in York are rather similar to the patterns of female cyclists, and the female samples in the former were larger than the female samples of the latter. A half of the York samples were females, while it was only 30% in Leeds. Therefore, the proportions of female cyclists also made a certain impact on the difference between Leeds and York.

The study segmented cyclists in two ways using confidence levels and route choice criteria. It is probably the first study which segments cyclists for route choices with non-socio demographics.

The analysis revealed that both typologies have a relationship. There were changes in the proportions of the criteria based cyclist types by the increase of confidence. These changes shows what the main interests are for cycling routes for different cyclist types: from safety to quick trips.

Lack in confidence strongly affected cyclists who prefer safer routes such as cycle lanes and wider lanes. The preference of less confident cyclists is for separation from moving vehicles. On the other hand, increased confidence makes cyclists take risks and become more tolerant to bad conditions. However, there was also a negative side in improvement of confidence, as more serious accidents were experienced by more confident cyclists.

The criteria based cyclist types provide hints for who should be targeted for cycling policies or improvement of infrastructures for cycling. *Worried Cyclists* and *Speedy Cyclists* represent two typical concerns of cyclists who cycle for commuting and utility. Their preferences and importance to route factors can be good references for cycling strategies depending on a main target and goals of the strategies and environment of individual cities.

Chapter 5 Analysis of Actual Routes

5.1 Introduction

Chapter 5 describes results of the analysis of the route data collected by GPS and the quality evaluation for the routes. The participants in the GPS data collection and interviews were chosen from the participants in the questionnaire survey. The samples aimed to create a balance in gender, city living, confidence levels and criteria-based types. However, a relatively small number of cyclists who were at the beginner level were recruited because not many at that level completed the questionnaire.

The analysis was carried out in 3 stages with the 2 data sets. The first stage of the analysis with the route data aimed to explore cyclists' behaviours, including trip distance, time and speeds. The second stage with route evaluation data identified differences in the quality of the selected routes via statistical analysis. The criteria and features which got good score are strengths of the routes and potentially reasons to choose them. The third stage compared pairs of the selected routes in a GIS map. In this stage, a researcher investigated the route based on the route evaluation; for example if a route was evaluated as good with scenery, it was checked whether or not it passed through a park area. This third stage identified key reasons for being different between the paired routes.

Section 5.2 describes the results of descriptive analysis for actual routes. Section 5.3 then presents results of the quality evaluation of the routes in group analysis. In section 5.4 the selected paired routes were compared individually with the route evaluation data and maps. Finally, discussion about the findings and conclusions are presented in section 5.5 and 5.6 in order.

The chapter only presented selected results in tables for statistical analysis results. All relevant full statistical results are presented in Appendix 5 and the information about participants is presented in Appendix 6-1.

5.2 Descriptive Analysis of Actual Routes

Table 5.1 shows an overview of the cycling behaviours of participants with the recorded data by GPS. There were significant differences between Leeds and York. Participants in York made more cycling trips per day while participants in Leeds cycled for longer times and distances, even registering as slightly faster. All the differences except for the number of cycling trips per day are due to the larger size of Leeds; as it is a bigger city there are longer distances and times for trips on average, as well as faster pedalling.

Table 5.1 Overview of Cycling Behaviours in Leeds and York

Behaviour	Total	Leeds	York
Cycling trip per day	2.43	2.02	2.86
Distance (km)	4.44	6.23	3.26
Trip time (minutes)	15.72	23.07	13.06
Trip speed (km/h)	17.28	17.06	15.46

In the following sections the results of statistical analysis are presented, including trip frequency, distance, times and speeds of cycling trips in order. The presentation focuses on differences by gender, trip purpose, confidence level and criteria-based cyclist types.

The T-test was used for comparisons by gender for each city, while the ANOVA tests were used for comparisons of trip purpose, confidence level and criteria-based cyclist types.

There are few comparable studies showing the cycling behaviours of cyclists based on actual routes, so rather limited comparisons were provided through the section.

5.2.1 Trip Frequency

Table 5.2 shows the average cycling trips made per person per day (per person-day). Individual participants made 2.4 one-way bicycle trips per day, with slightly more cycling trips seen with participants in York (2.9 trips) than Leeds (2.0 trips). It is comparative that cyclists in Newcastle, UK made 1.2 cycling trip per day on average (Yeboah, 2014) while cyclists in Portland, USA made 1.6 trips per day (Dill and Gliebe, 2008). It is rather interesting as cyclists in Leeds made more cycling trips than in Newcastle or Portland because the rate of cycling use for commuting is lower than the rates of Newcastle.

Table 5.2 Number of Cycle Trips per Person-Day

Category		Total(47)	Leeds(24)	York(23)
Gender	Male(26)	2.4	1.9	3.0
	Female(21)	2.4	2.1	2.7
Trip purposes	Commuting	1.3	1.6	1.1
	Personal	0.8	0.4	1.3
	Business	0.3	0.0	0.5
Confidence level	Beginner(5)	2.1	2.2	2.0
	Unconfident(12)	2.1	1.9	2.2
	Confident(19)	2.6	1.8	3.3
	Very confident(11)	2.7	2.4	2.9
Criteria types	*Heavenly*(9)	2.7	2.2	3.5
	Worried(10)	2.4	2.0	2.7
	Speedy(14)	2.4	1.8	3.1
	NTI(14)	2.3	2.2	2.4

(Number) : The number of participants for the category

There was no clear difference between men and women for cycling frequency, as males in York cycled more than females while men in Leeds cycled less. This is an unexpected finding, but the differences were not significantly large. The reason for this unexpected result with Leeds is because one of female cyclists there cycled an exceptionally long distance for commuting purposes.

Clear differences in the cycling trip frequencies of cyclists between Leeds and York appeared with trip purposes. Cyclists in Leeds cycled for commuting in most cases, while cyclists in York cycled more for personal purposes such as visiting a friend than commuting. There were also more business trips made in York because a few participants there were self-employed and made mostly business purposed trips. Therefore, the results show that participants in York cycled for a wider range of activities.

The questionnaire showed that cyclists in York cycled more frequently, and the cause of this seems to be because of more cycling activities for personal and business purposes.

5.2.2 Trip Distances, Times, and Speeds

Table 5.3 shows the distances, times, and speeds of cycling per trip on average. Trip times were strongly related with trip distances and speeds together.

Table 5.3 Trip Distances, Times, and Speeds

	Distance (km)		**Time (min)**		**Speed (km/h)**	
	Leeds	York	Leeds	York	Leeds	York
Gender*						
1. Male	6.3	3.0	21.4[2]	11.4[2]	18.2[2]	16.6[2]
2. Female	6.1	3.6	25.2[1]	15.0[1]	15.6[1]	14.1[1]
Trip purpose†						
a. Commuting	6.7[b,c]	4.4[b,c]	24.5[b]	16.2[b,c]	17.6[b,c]	16.5[b,c]
b. Personal	4.6[a]	2.6[a]	18.1[a]	11.1[a]	15.5[a,c]	14.9[a]
c. Business	2.4[a]	2.5[a]	15.1	11.1[a]	10.4[a,b]	14.6[a]
Confidence level†						
a. Beginner	4.2[c,d]	4.8	19.5[d]	24.8	14.9[c,d]	14.0
b. Unconfident	5.4[d]	4.9[c,d]	22.2	17.4[c,d]	15.5[c,d]	15.8
c. Confident	6.4[a]	2.8[b]	22.5	11.8[b]	18.2[a,b]	15.0[d]
d. Very confident	8.3[a,b]	2.7[b]	27.2[a]	10.8[b]	18.6[a,b]	16.2[c]
Criteria types†						
a. Heavenly	8.1[b,d]	2.5[d]	29.6[b,d]	10.0[d]	16.1	15.5[d]
b. Worried	5.6[a]	2.9[d]	21.8[a]	13.0	16.8	14.6[d]
c. Speedy	6.9[d]	2.7[d]	25.2[d]	11.7[d]	18.2	14.8[d]
d. NTI	4.9[a,c]	5.3[a,b,c]	18.0[a,c]	18.1[a,c]	17.0	17.3[a,b,c]

* Items in superscript indicate significant difference from each other (T-tests)

† Items in superscript indicate significant difference from each other (ANOVA post hoc analysis (Dunnett T3))

Although there was no statistical difference in the distance cycled between males and females for each city, the average trip distance per trip by male cyclists in Leeds was slightly longer than that for females (Aultman-Hall et al., 1997; Yeboah, 2014). However, in York, female cyclists cycled a little longer than male cyclists. The analysis of the questionnaire showed that cycling activities by females in York were very active, so this may have influenced longer trips by female cyclists in that city.

Unlike the trip distances by gender, there were significant differences in trip time by gender. Female cyclists took longer times for cycling than males. However, these differences were due to the trip speeds. The average trip speeds of female cyclists were much slower than for males.

Regardless of gender, cyclists in Leeds cycled faster than cyclists in York. This is partially because cyclists in Leeds might have wanted to reduce trip times with increased speeds. These average cycling speeds were much slower than the speeds found in the other studies. The study of Parkin and Rotheram (2010) found that the average speed of cycling was 21.6km/h in Leeds with 16 participants, while the average speed of cycling in Portland, USA was 17.4 km/h (10.8 mph), which is fairly similar to the average speed in Leeds found in the thesis. However, the trip speeds in York were fairly lower than the other cases. This is maybe also due to relatively short trip distances. As shown in the average trip times, most trips in York were made within 15 minutes, so cyclists there may not need to speed up for their trips.

The differences in cycling behaviours by trip purposes were significant, but as expected. Cyclists cycled longer in distance and time and faster for commuting.

In terms of differences by confidence level, the average trip distance of the cyclists at the beginner or unconfident level in York was longer than the distance of the cyclists at confident or very confident, while in Leeds the distance increased with the increase of confidence. This rather odd result in York was partially caused by the odd behaviours in cycling of one participant in York. The participant cycled a long distance for commuting, but she was segmented as an unconfident cyclist while there were also participants who cycled a long distance but were segmented as confident or very confident cyclists. Although the participant in York may be an odd sample, it also reflects that the cycling environment for long distance in York may be better than in Leeds, even for unconfident cyclists.

The trip time took much longer with the slower trip speed of less confident cyclists, especially with the cases of Leeds. There was little differences between less confident cyclists (Beginner and Unconfident) in Leeds and York in the distance, time and speed whereas there were significant differences between more confident cyclists in the cities and between more confident cyclists and less confident cyclists in Leeds. Increased confidence significantly increased trip distance and speeds of cyclists in Leeds, and more confident cyclists reduced trip times for longer distances with the faster speeds. However, in York the trip speeds were rather stable regardless of confidence levels, with the lowest speed of the cyclists at beginner level.

In terms of differences by criteria types, they were rather unclear as there was no clearly noticeable pattern. However, two points could be identical. The cycling behaviours of *Heavenly Cyclists* between Leeds and York heavily contrasted. The *Heavenly Cyclists* in Leeds cycled for long distances and slowly, while The *Heavenly Cyclists* in York cycled for short distances and fairly fast, meaning faster than the other types in York. Although they were categorised into the same type, their characteristics were rather different.

Another point is the cycling behaviours of *NTI cyclists*. The behaviours of them in these cities were almost the same as each other, even with trip distances.

The criteria and confidence segments for cyclists were not developed for cycling behaviours, so their influences on the behaviours are limited. However, the confidence seems more influential than the criteria types.

5.2.3 Discussions about Cycling Behaviours

There was a question raised by the results above. It seems that cycling behaviours were more influenced by different geographical characteristics of the cities, especially the size.

Table 5.4 shows the distributions of cycling trip distances of Leeds and York in percentage. In York, the majority of cycling distances was under 4 km (80.8%), which is similar to the results of the London Travel Demand survey in which the majority (80%) of cycling distances in London was less than 5 km (TfL, 2010), whereas the study of Dill and Gliebe (2008) showed that the majority of trip distance was under 6 km. We can see that 4, 5, or 6 km trips all take less than 25 minutes, so the majority of cyclists seem to make cycling trips within 25~30 minutes.

On the other hand, the pattern of trip distances in Leeds was rather different from York. More cycling over 4km were made in Leeds (65.7%), with the high proportion of relatively long distances cycling over 8 km.

Table 5.4 Distribution of Distances of Cycling Trips

Miles per trip	Leeds (N=242)	York (N=329)
1km or less	7.4%	12.2%
>1 to 2km	7.0%	25.2%
>2 to 3km	8.3%	24.3%
>3 to 4km	11.6%	19.1%
>4 to 5km	8.7%	5.8%
>5 to 6km	9.5%	4.6%
>6 to 7km	9.9%	1.2%
>7 to 8km	7.0%	2.1%
>8 to 9km	11.2%	1.8%
>9 to 10km	2.9%	0.0%
More than 10km	16.5%	3.6%

These results are because the size of Leeds is larger than York. The distances from the city centre to the inner boundaries within which most of the trips were made were around 6 km for Leeds and 4km for York. These figures of 6 km and 4 km were similar to the average distances of the cycling trips for each city of 6.23 km for Leeds and 3.26 km for York. So the distance of cycling and the size of a city have a positive correlation but with the limit of a certain trip time, which seems 25~30 minutes.

The 25~30 minute limit can be explained by the case of London, which is a bigger city than Leeds. However, the majority of the cycling activities even in London were made within 5 km (TfL, 2010) while the majority of cycling in Leeds was made over 4 km. This is possibly due to different urban living sectors between the two cities. London can be divided into several sectors and has several downtowns, so cycling trips may be made within the smaller boundaries rather than crossing London. On the other hand, Leeds is not big enough to divide the city into a few living sectors but also rather big for cycling activities within 4~5 km distances, so a certain group of cyclists in Leeds seem to accept slightly longer distances for cycling trips.

The results potentially indicates that planners need to find optimum distances for cycling activities for a city, and this distance should be within 30 minutes trip times. Planners then need to make plans for developing cycling networks or else within the boundary that the planners found for the city to maximise cycling activities.

5.3 Analysis of Route Evaluation Data

5.3.1 Overview and Differences by City

Participants evaluated the selected actual routes for 5 route choice criteria and 22 features of routes. Table 5.5 shows statistical results of the evaluation with selected items.

Table 5.5 Evaluation of the Quality of Routes – Comparison by City

	Leeds	York	Sig.
Route choice criteria			
Minimising distance*	5.0	5.7	p=.028
Minimising time*	5.1	5.8	p=.012
Safe route	4.8	4.9	p=.580
Reliable route	5.6	5.7	p=.529
Pleasantness/Comfort	4.5	5.0	p=.163
Route feature			
Traffic volume*	3.4	4.5	p=.000
Lane width*	3.7	4.7	p=.001
Cycling facilities*	3.4	4.9	p=.000
Vehicles parked on street*	3.8	4.8	p=.001
Residential roads*	4.6	5.4	p=.002
Roundabouts*	3.9	4.7	p=.020
Signalised junctions*	4.3	4.9	p=.015
Give-way junctions*	4.2	5.0	p=.001
Making left turns*	4.9	5.6	p=.000
Uphill*	4.0	5.4	p=.000
Surface*	4.0	4.9	p=.000
Bicycle parking*	4.6	5.5	p=.023
Pedestrian-oriented areas*	3.9	5.2	p=.001
Lightings (in darkness) *	4.5	5.2	p=.014

* Significance at 95%
Full version of results are in Appendix 5-1

The quality of cycling routes in York was better than the routes in Leeds. Cyclists in York were more satisfied with their chosen routes than in Leeds regarding minimising trip distance and time, while pleasantness/comfort was also better in York, but not statistically significant. However, the overall trip distance and times in York were shorter than in Leeds, so it should be considered that the perceived quality of cyclists for distance and time in Leeds cannot be better than in York in nature.

The quality of routes for safety was relatively lower than the other criteria except for pleasantness/comfort in Leeds, meaning that safety is still a problem for cycling routes in both Leeds and York. On the other hand, these results can be thought to indicate that cyclists chose the routes basically to arrive at a destination as soon as possible rather than with safe or comfortable ridings.

In terms of route features, there was no feature with a score of below 4.0 in York while there were several features scores below that in Leeds. In addition, the measure quality of individual features in Leeds was close to a score of 4.0, so the overall quality of the routes chosen in Leeds was not good but also not too bad.

5.3.2 Differences by Gender

Differences by gender were separately analysed each for Leeds and York as looking at them together made the differences weaker than a separated analysis.

The results are presented in Table 5.6 heavily contrast between Leeds and York by gender. The female cyclists in Leeds were less satisfied with the quality of the features of their routes than the male cyclists, while the female cyclists in York were more satisfied than the male cyclists except for the quality of main roads, which was lower in score (3.8) than males (4.2).

Table 5.6 Evaluation of the Quality of Routes – Comparison by Gender

Route feature - Leeds	**Male**	**Female**	**Sig.**
Cycling facilities*	4.0	2.8	p=.004
Main roads*	4.3	3.3	p=.001
Roundabouts	4.2	3.6	p=.326
Uphill	4.3	3.8	p=.271
Downhill*	5.7	4.8	p=.036
Route feature - York			
Lane width*	4.3	5.1	p=.027
Signalised junctions*	4.5	5.3	p=.025
Making left turns*	5.1	6.1	p=.000
Uphill	5.3	5.7	p=.179
Main road	4.2	3.9	p=.487

* Significance at 95%
Full versions are in Appendix 5-2 and 5-3.

It is particularly important that there were large differences in the perceived quality of cycling routes between female cyclists in Leeds and York. One of the core problems with cycling environments in Leeds was the cycling facilities, of which the measured quality was only 2.8, the lowest score given. This clearly indicates that a lack of cycling infrastructure in Leeds is a problem of preventing females cycling.

On the other side, the female cyclists in York were relatively satisfied with their actual routes. However, they also gave a low score to the quality of main roads, so overall the quality of main roads was not good for females to cycle along regarding the cities.

5.3.3 Differences by Trip purposes

The thesis collected a large number of the route evaluation data for personal trips in York and compared those with the evaluation data for the routes with other purposes. However, statistical analysis revealed that there was no significant difference between personal trips and the other purposed trips except for trips coming back home. Even the differences between the quality of the routes for personal trips and the quality of the routes for trips back home were only significant in minimising trip time and distance (Table 5.7).

Table 5.7 Comparisons of Quality of Routes between Personal, Commuting, and Back-home Routes (York)

Route choice criteria	Personal	Commuting	Back home
Minimising distance*	5.9	5.6	4.0
Minimising time*	6.0	5.8	4.1
Safe route	4.9	4.9	5.0
Reliable route	5.8	5.8	5.3
Pleasant/Comfort	4.9	4.8	6.0

* Significance at 95% between back-home routes and personal trip or commuting routes
Full version is in Appendix 5-4.

The analysis found that cyclists chose routes returning home from work for more relaxed and enjoyable cycling. Although it was not statistically significant, pleasant/comfort was the most important criteria for back-home routes. This result is similar to the findings in the study of Dill and Gliebe (2008), which found that trips returning home were chosen under different priority of influencing factors and were more like recreational and social trips than commuting trips. On the other hand, these findings are rather opposite to the findings of Yeboah (2014), in which going–to-work trips were only different from all the other trips. However, the study of Yeboah was about usages of cycling network while the thesis and the study of Dill and Gliebe were about choice criteria.

5.4 Comparative Analysis with Actual Routes

Participants showed distinctive characteristics with their routes. One group of participants used basically a single route for their commuting (the same routes for both going to work and coming back home), while another group used 2 different routes for their commuting trips, which means they chose different routes for trips for going to work and coming back home. There were also several variations or alternatives for commuting routes. The terms of variations and alternatives were explained in section 3.6.3.1.

The comparisons were carried out in 2 ways: between to-work route and back-home routes and between main routes and alternative routes. The purpose of these comparisons is to find key reasons or factors which made cyclists choose different routes from mainly used routes. These differences will explain choice matters for routes in real situations.

5.4.1 To-work Routes Vs Back-home Routes

5.4.1.1 Cases in Leeds

To-work routes and back-home routes were explained in 3.6.3.1. In total, 13 out of 24 participants in Leeds had different routes when they went to work and came back home. Table 5.8 shows results of the descriptive analysis.

Table 5.8 Trip Times and Distances Between To-work routes and back-home Routes

Characteristics	To-work	Back home	Difference
Time (min)	24.1	30.0	5.9
Distance (km)	7.2	7.7	0.5

To-work routes were shorter in time and distance in average than back-home routes. The average distance of back-home routes was 0.5 km longer than to-work routes, while back-home trips took 5.9 minutes more than to-work trips. Therefore the analysis said that participants in the group chose a little longer distance route when they came back home and spent more time.

However, in details only 4 cases had significant differences in distance and time, while the other cases had differences of less than 300 m in distance (300m is actually not significantly different when considering errors in GPS data).

This shows that making average values with small samples can neutralise the value of data, so the analysis were made with individual cases separately and took features from the cases. Four key features were derived via the analysis with individual cases.

Taking benefit of downhill for to-work routes

To-work routes were better than back-home routes in minimising distance, time and safety, but they were worse in pleasantness/comfort. It was clear that cyclists chose a route to minimise trip distance and time for trips for going to work while they chose a different route when coming back home for comfortable riding.

One of key characteristics of to-work routes was that they had an advantage in going downhill, which would save trip time and physical efforts. Cyclists gave a statistically significant higher score to downhill for to-work routes (Table 5.9). This was possible as the central area in Leeds is lower than the surrounding areas. Overall cyclists evaluated that a downhill gradient was much better for to-work routes than back-home ones.

Table 5.9 Route Quality Comparison between To-work Routes and Back-home Routes in Leeds

Route choice criteria	**To-work**	**Back home**	**Sig.**
Minimising Distance	5.8	4.5	p=.085
Minimising time*	6.1	4.5	p=.010
Reliable route	5.3	5.0	p=.736
Safe route*	6.4	5.4	p=.018
Pleasant/Comfort	4.8	5.1	p=.471
Route features			
Give-way junctions	3.8	5.0	p=.074
Downhill*	6.0	4.5	p=.031
Good scenery	2.4	4.4	p=.086

* Significance at 95%
Full version is in Appendix 5-5.

Further analysis identified a few important features from the compared routes. Pairs of the routes can be categorised into 3 different types by the patterns of having a different back-home route: Completely different pairs of routes, major detoured pairs of routes and partially detoured pairs of routes.

Type 1: Better scenery (benefits of back-home route)

In terms of the back-home routes, which were completely different from the paired to-work routes, cyclists chose a better route in scenery, which was the most significant characteristic of the back-home routes in this type. The participants gave an average score of 7 to scenery in the quality evaluation. This shows that good scenery or freedom from traffic related stress was an important rationale in the choices.

Table 5.10 Comparisons of Route Quality in Type 1 Back-home Routes

Route choice criteria	To-work	Back home
Pleasant/Comfort	4.0	6.0
Reliable route	3.7	5.3
Route features		
Good scenery	***1.7***	***7.0***
Cycling facilities	4.7	5.7
Pedestrian-oriented areas	2.5	5.0
Residential roads	4.0	5.0
Traffic volume	2.3	3.7
Traffic speed	4.3	5.0
Buses	3.3	4.7
HGVs	2.3	4.3

These back-home routes featured longer distances than the paired to-work routes. Cyclists indicated that most traffic related features were better with back-home routes, but scenery, cycling facilities and pedestrian oriented areas were generally superior

The inspection with the routes on maps showed clearer differences between to-work routes and back-home routes in this type (Figure 5.1). However, giving a priority to scenery did not mean that all the sections of a route were in green areas. In Figure 5.1 the to-work route in blue followed an A road while the back-home route in red followed the B road and a partially residential and green area. Although both A-road and B-road are arterial roads, the quality that cyclists felt about them was different. The participants for these route pairs felt the B-road was better in the quality for cycling regarding traffic volume, speed, buses and HGVs.

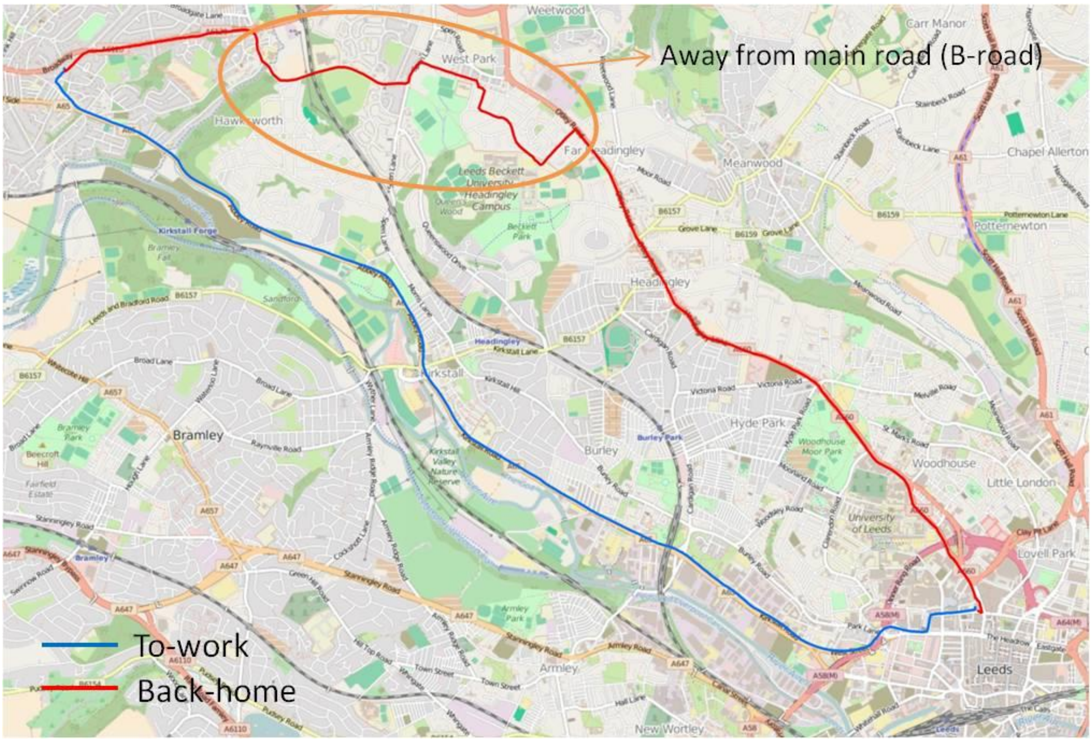


Figure 5.1 An Example of a Completely Different Back-home route from To-work Route (L17)

Type 2: Less uphill (benefits of back-home route)

In terms of the back-home routes, of which the major section was detoured from the paired to-work routes, hilliness was an important factor for the choices. Cyclists got a benefit from downhill to-work routes, but this benefit became a disadvantage when they came back, so they chose less hilly routes for back-home options. This difference was quite difficult to detect as the average gradients did not say meaningful differences between the pairs of the routes.

Figure 5.2 shows an example of altitudes of the paired routes of this type. However, the quality evaluation clearly indicated that back-home routes had an advantage with the downhill gradient (Table 5.11). However, the back-home routes in this type did not have any advantages with the route choice criteria.

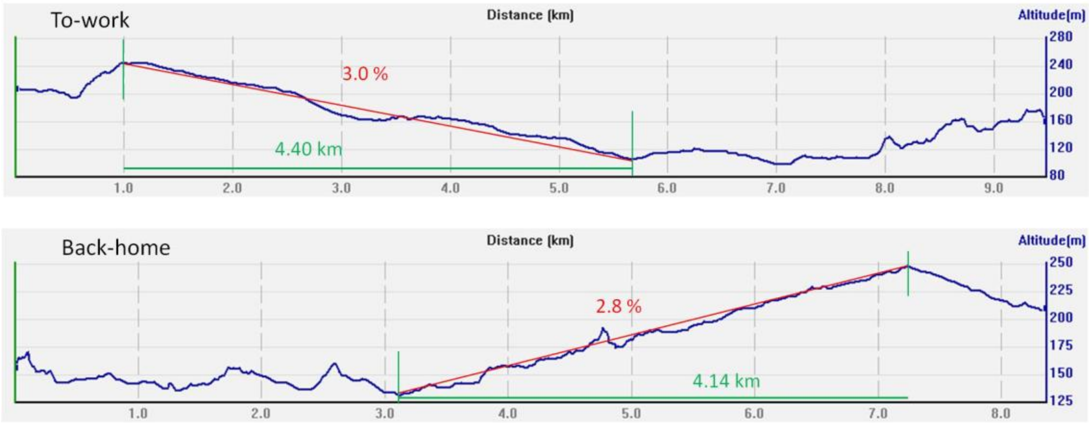


Figure 5.2 An Example of a Comparison of Altitude of The Routes in Type 2 (L3)

Table 5.11 Comparisons of Quality of the Routes in Type 2

Route choice criteria	To-work	Back home
Minimising Distance	5.7	4.3
Minimising time	5.3	4.3
Reliable route	6.3	4.7
Safe route	6.7	5.0
Pleasant/Comfort	5.7	4.7
Route features		
Uphill	***4.0***	***5.3***
Downhill	***6.3***	***4.7***

However, the back-home routes did not mean that they were not hilly, but rather meant that the back-home routes were relatively less hilly than the to-work routes. For example, the average downhill gradient of the case of L3 was 3.1%, but L3 cyclist used a different back-home route with the uphill gradient of 2.6% instead of using the same to-work route with an uphill gradient of 3.1%.

Table 5.12 Comparisons of Route Gradient in Type 2

		To-work	Back home
L3	Uphill gradient (%)	2.6	2.6
	Downhill Gradient (%)	3.1	2.7
L12	Uphill gradient (%)	2.5	1.6
	Downhill Gradient (%)	2.6	2.2

Type 3: Forced detour

The majority of the cases in this comparison belonged to this type 3. In terms of the back-home routes of which the minor section was detoured from the paired to-work routes, cyclists actually did not see any benefit in the back-home routes as all the conditions of the to-work routes were better than the paired back-home routes in the evaluation. However, these choices were rather forced. The partial changes of route sections were made for various reasons, such as visiting a shop on the way, one-way sections of roads or just their convenience.

Figure 5.3 shows an example of the types. The cyclists had 2 different sections between the to-work and back-home routes. The section at the top-right was due to visiting a shop while the section on the bottom-left was for convenient cycling, which means that moving forward at the section then turning made the cyclists cross the road only once.

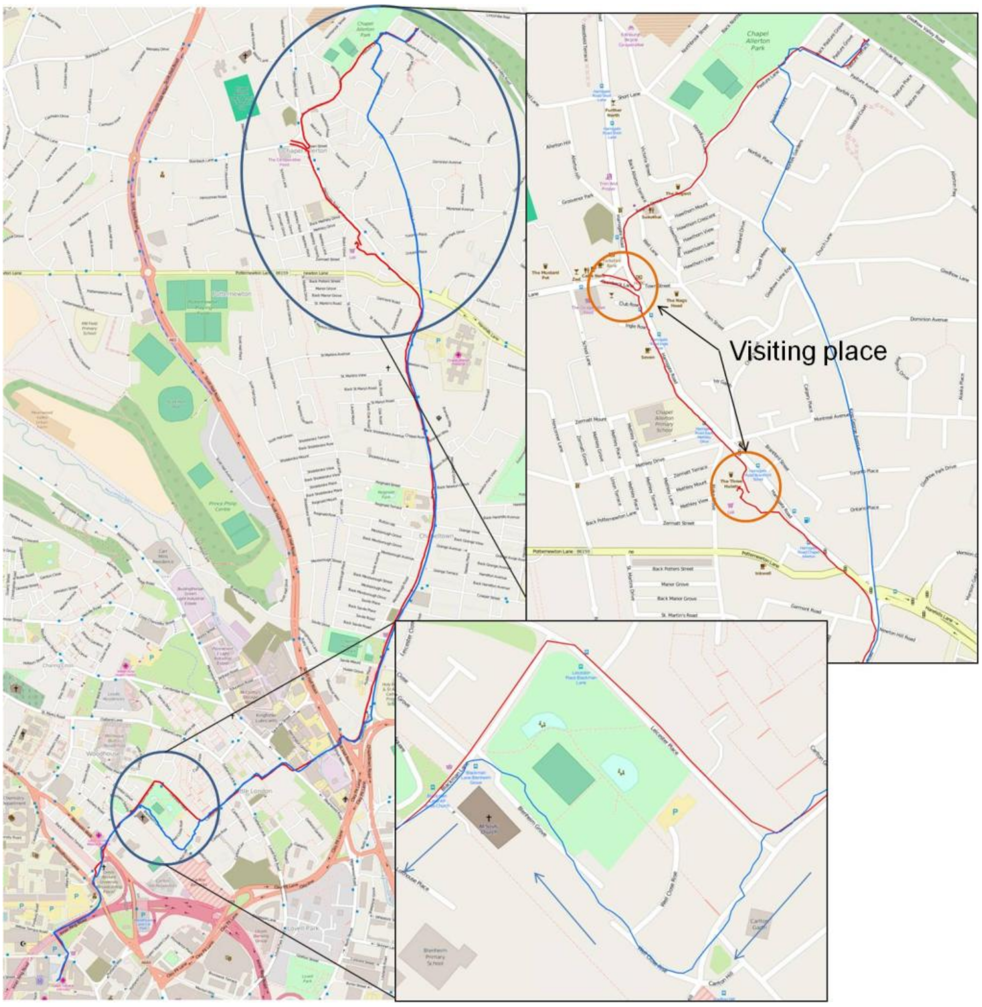


Figure 5.3 Example of Partial Detours in Type 3 (L1)

The route evaluation also showed that there were no significant differences between them (Table 5.13). In addition, the quality of to-work routes was overall better than back-home ones. Only making turns were slightly better.

Table 5.13 Comparisons of Quality of the Routes in Type 3

Route choice criteria	To-work	Back home
Minimising distance	6.5	5.5
Minimising time	6.5	5.5
Reliable route	6.0	5.0
Safe route	6.0	5.5
Pleasant/Comfort	4.5	4.5
Route features		
Traffic volume	3.0	1.5
Traffic speed	3.0	2.5
Lane width	3.0	2.0
Making right turns	*3.5*	*4.5*
Making left turns	*3.5*	*4.5*
Uphill	3.5	2.0
Downhill	5.0	4.5
Surface quality	4.5	3.5

5.4.1.2 Cases in York

In total 10 participants in York were included for the comparative analysis of the pairs of to-work and back-home routes. The differences in distance and time were not large, as the overall route length in York was shorter than the route length in Leeds. To-work routes were 330m shorter on average in distance than back-home routes. However, the difference of 330m means that there was actually no difference in distance when we consider errors in GPS data.

Unlike the cases of Leeds, the comparisons between to-work routes and their count back-home routes in York did not show any clear factors which made cyclists choose different routes.

According to the evaluation data (Table 5.14), to-work routes were better for minimising distance and time while back-home routes were better with pleasant/comfort. However, the quality evaluations for the route features did not clearly indicate the differences for good scenery. Only making right turn was significantly better for the back-home routes.

Individual investigations with each case did not clearly show an improvement in making a right turn with the back-home routes. However the investigation gave a strong signal that the cyclists chose the different route for the convenience of going through at a junction or passing roundabouts.

Table 5.14 Route Quality Comparison between To-work Routes and Back-home Routes in York

Route choice criteria	To-work	Back home	Sig.
Minimising distance	5.5	4.0	p=.186
Minimising time	6.2	4.3	p=.107
Reliable route	4.5	4.7	p=.904
Safe route	6.0	5.2	p=.444
Pleasant/Comfort	4.7	5.8	p=.242
Route features			
Making right turn*	2.8	5.0	p=.011
Good scenery	4.2	4.5	p=.768

* Significance at 95%
Full version is in Appendix 5-6.

Figure 5.4 shows an example of how cyclists change their routes due to roundabouts. When a cyclist went to work (blue line) he simply chose a route going forward at a roundabout, whereas when he came back home (red line) he also chose to keep moving forwards at a T-junction on the top-right before then using a roundabout. It seems that he chose routes for minimising the stress from turning at a junction, and it also related to a junction size that the roundabout on the bottom left is bigger than the one on the bottom right, so the bottom right one might be easier to use.

Another example in Figure 5.5 was also similar to the case of Figure 5.4. The routes were changed at a roundabout. This cyclist also chose routes for easier use of the roundabout.

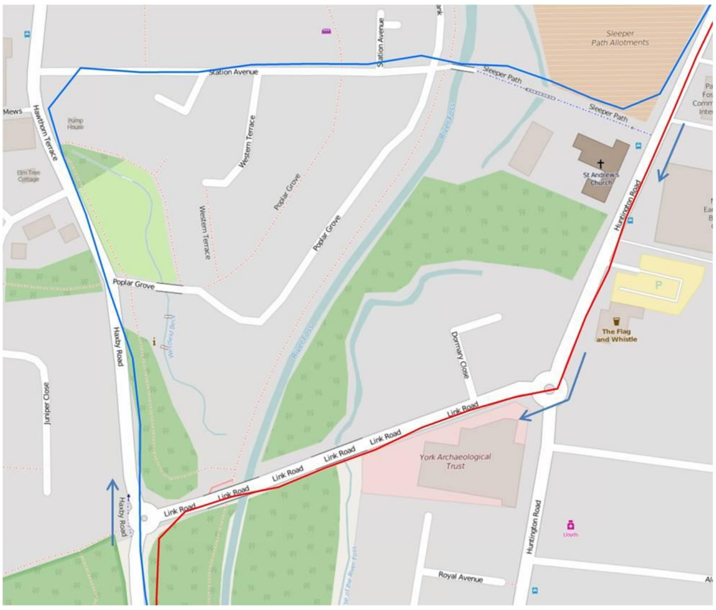


Figure 5.4 Example of Detouring by Junction (Y10)

Figure 5.5 Example of Detouring by Junction (Y9)

5.4.2 Main Routes Vs Alternative Routes

This section presents the results of the comparative analysis with main routes and their alternatives. The pairs of the routes used for the analysis share the same origin, destination and purpose, but their courses were very different.

There were 3 different alternative routes: alternatives to to-work routes, alternatives to back-home routes and alternatives to commuting routes. For example the alternatives to commuting routes means that a main route is a route used for round trips between the work place and home, while the alternative is a route occasionally used instead of the main commuting route. There were no alternative routes recorded for personal and business trips.

5.4.2.1 Cases in Leeds

Eleven participants had at least one alternative to their main routes. Ten cases were for alternatives to to-work routes, while seven cases for alternatives to back-home routes and only one case for an alternative to a commuting route were found.

Table 5.15 shows descriptive comparisons between the main routes and their alternatives. The alternatives were 1.4 km longer and took 7 minutes more on average than the mains.

Table 5.15 Distance and trip time between main routes and alternatives in Leeds

Variable	Main	Alternative	Difference
Distance (km)	7.6	9.0	1.4
Time (min)	27.4	34.4	7.0

The route evaluation in Table 5.16 shows what cyclists importantly think of the main routes and alternatives respectively. Cyclists gave higher scores to the main routes for minimising trip distance and time with statistically more significance than the alternatives while giving a higher score to the alternatives for pleasant/comfort without a statistical significance.

In terms of the route features, the quality of most of the route features were better with the alternatives except for downhill, parked vehicles and residential roads, though the differences were not statistically significant with most features. Overall quality of the alternative routes were better. However, the key reason that cyclists had alternative routes was for better scenery.

The score for good scenery for the alternatives was especially higher than the main routes with a statistical significance.

Table 5.16 Route Quality Evaluation between Main Routes and Alternatives in Leeds

Route choice criteria	Main	Alternative	Sig.
Minimising Distance*	6.0	3.4	p=.001
Minimising time*	5.9	3.4	p=.001
Reliable route	5.7	5.3	p=.985
Safe route	5.1	5.1	p=.556
Pleasant/Comfort	4.6	5.4	p=.412
Route features			
Cycling facilities	3.0	4.3	p=.208
Good scenery*	3.9	5.9	p=.025

* Significance at 95%
Full version is in Appendix 5-7.

Figure 5.6 shows an example of how different the alternative routes were from the main routes. The cyclist for these routes used mainly A roads for the main cycling route to work. However, the cyclists also had an alternative route, but it was less frequently used and detoured a lot through a park area.

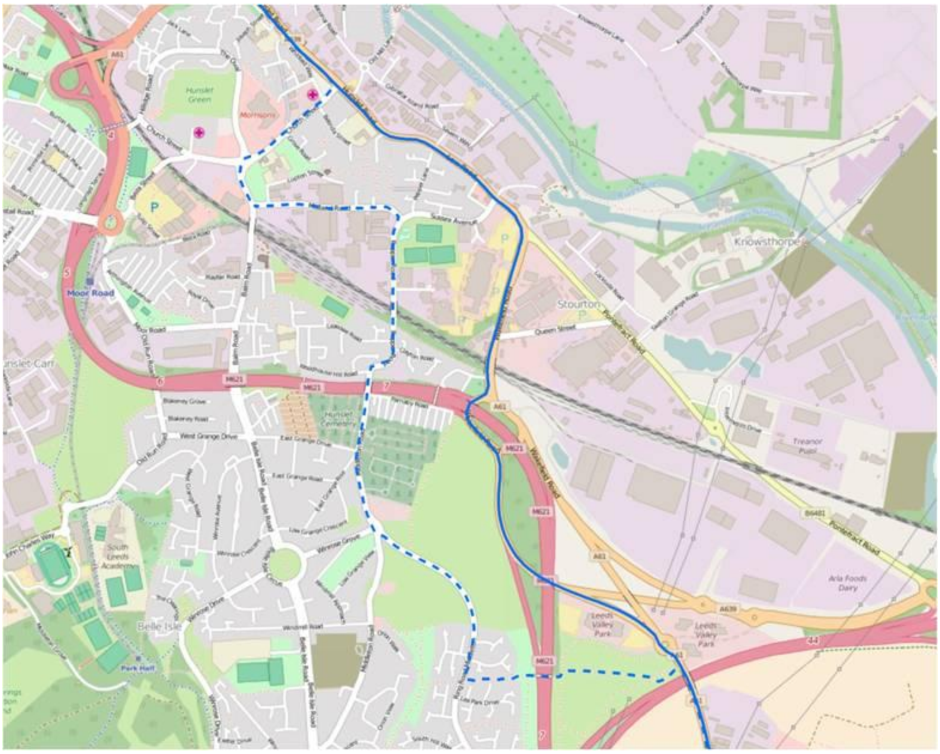


Figure 5.6 Example of Main Routes and Alternative Routes for Better Scenery (L6)

5.4.2.2 Cases in York

Nine participants had at least one alternative route to their routes: 5 cases for alternatives to to-work routes, 3 cases for alternatives to back-home routes and 5 cases for alternatives to commuting routes.

Table 5.17 shows the average values of trip distance and time between the mains and alternatives. The alternative routes were 1.0 km longer and took 5 minutes more than the main routes. These tendencies were similar to the cases of Leeds.

Table 5.17 Distance and trip time between main routes and alternatives in York

Variable	Main	Alternative	Difference
Distance (km)	6.1	7.1	1.0
Time (min)	22.5	27.5	5.0

The route evaluation data shows fairly interesting results (Table 5.18). Alternative routes were significantly worse than main ones, which is a completely opposite result from the cases in Leeds. For those cases cyclists used alternative routes for better quality in pleasant/comfort, even with scarifying distance. However, in York cyclists used alternative routes as they were more reliable, although it was not statistically significant. With the route features, most of features were better with main routes.

Table 5.18 Route Quality Evaluation between Main Routes and Alternatives in York

Route choice criteria	Main	Alternative	Sig.
Minimising distance	5.4	5.1	p=.762
Minimising time	5.4	5.0	p=.679
Safe route	5.3	4.5	p=.399
Reliable route	5.1	5.6	p=.555
Pleasant/Comfort*	6.0	3.6	p=.028
Route features			
Traffic volume	5.0	3.0	p=.061
Traffic speed	5.0	3.4	p=.133
Lane width	5.0	3.9	p=.245
Buses	4.9	3.5	p=.199
HGVs	5.4	3.6	p=.086
Cycling facilities	4.9	4.1	p=.333
Vehicles parked on street	5.3	4.4	p=.246
Main roads	4.3	2.7	p=.106
Good scenery*	6.4	3.6	p=.001

* Significance at 95%

It was difficult to detect the factors or reasons for having alternative routes only with the quality evaluation data. The analysis with individual cases on a map showed the reasons why cyclists indicated that the main routes were better for most of the route features. The alternatives were divided into 2 types. The first one was that main routes followed the cycleway or green area, so most of the route features were better than alternatives, while the alternatives were more reliable and better for lighting and surface quality as they followed main arterial roads.

Figure 5.7 shows an example of the first cases. In the figure, green lines are the cycleway and the main route (blue line) used the cycle way which is partially along the river while the alternative followed A roads in most of the sections. The reason that cyclists indicated the alternatives were more reliable was not found in this analysis, but in the analysis of the qualitative phase (see Section 6.2.2)

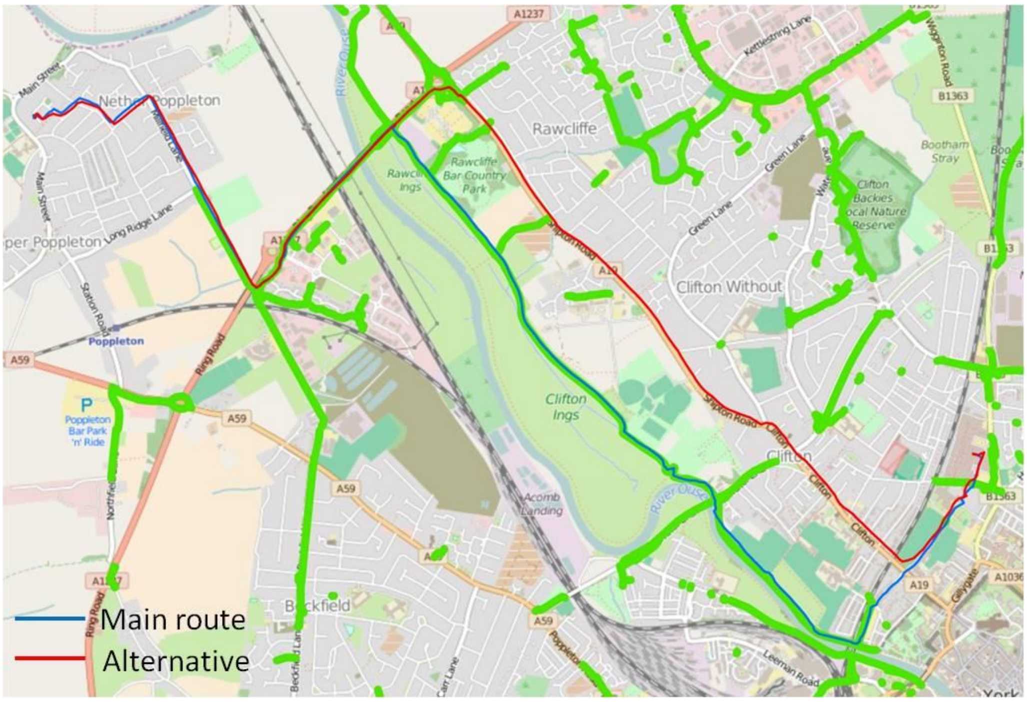


Figure 5.7 Example of More Reliable Alternative Routes in York (Y2)

The second type was that alternatives were chosen to visit a certain place so the alternatives were more direct to a visiting place. This type is similar to the forced route in the cases in Leeds. As shown in Figure 5.8, the cyclist needed to visit a certain place on the way to work, so he chose a different route from the one that he usually used (blue line) as it was more direct. However, the alternative also had several benefits, such as less traffic, as it was mainly along residential roads.

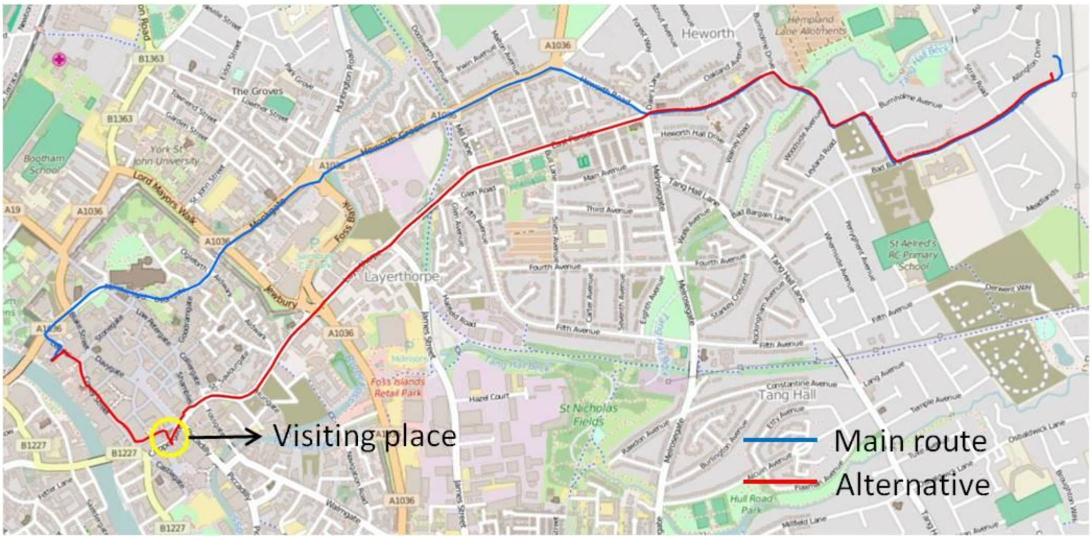


Figure 5.8 Example of Forced Routes in York (Y11)

5.5 Discussions

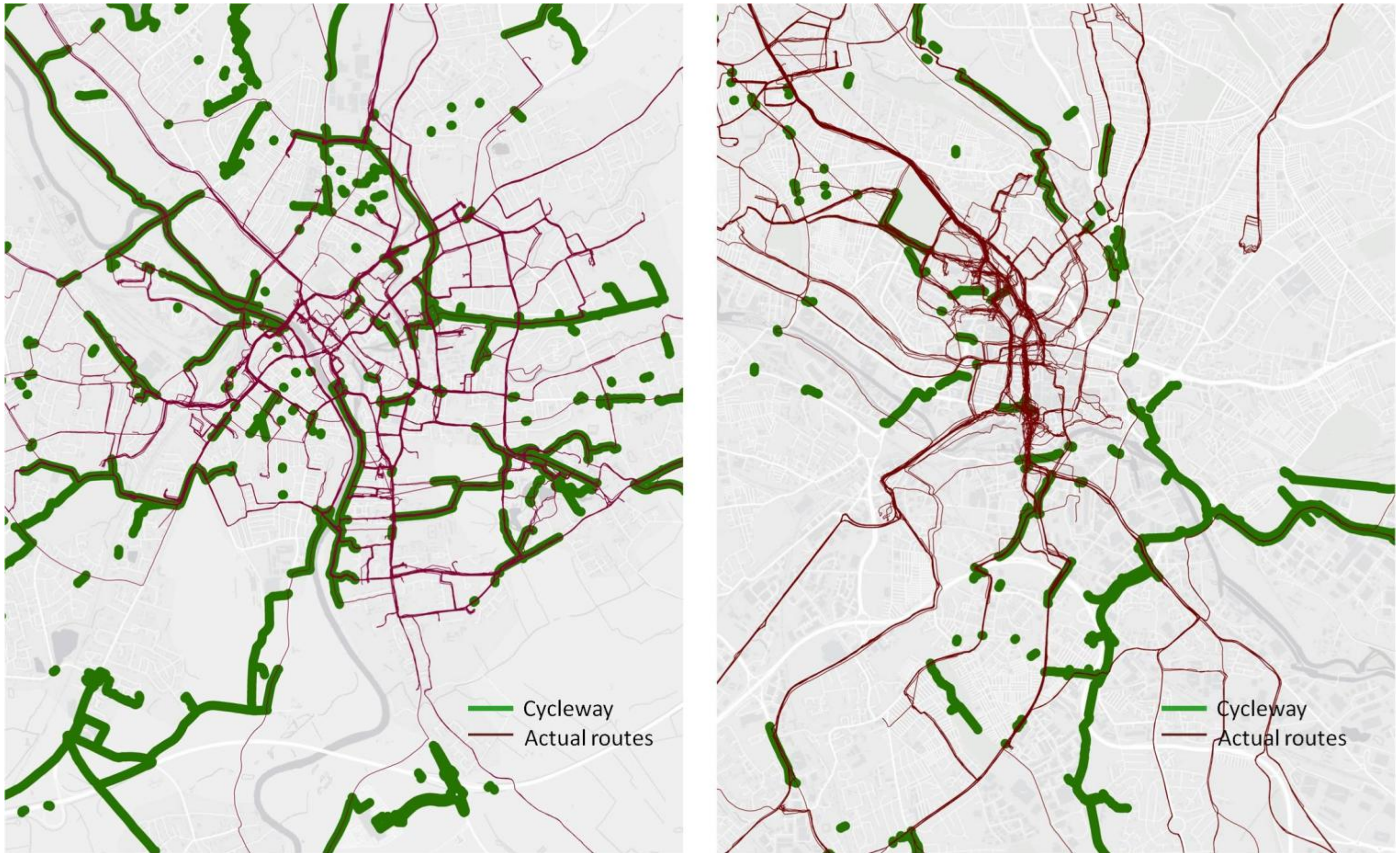
Female cyclists and cycling Facility

As shown in the questionnaire and actual route data, female cyclists in York were very active in cycling and frequently cycled for non-commuting purposes. What makes this difference? This active cycling by female cyclists in York is possibly because of the better infrastructures there.

It was obvious that cyclists in Leeds seemed to have strong demands for comfort and pleasant cycling routes, which was the key reason that they had alternative routes or different back-home routes, whereas the mainly used routes by cyclists in York were better in quality, even for comfort and pleasantness, than the alternatives.

There were important differences in the route evaluation between female cyclists in Leeds and York. Route choice criteria and patterns of choosing routes were not differentiated by gender. However, female cyclists in York evaluated that the features of their routes were fairly good while female cyclists in Leeds evaluated that the features of their routes were fairly bad. Cycling facilities were an important factor regarding these opposite evaluations to their routes. Female cyclists in Leeds particularly gave the lowest average score to the quality of the cycling facilities.

What are the significant differences between cycling facilities in Leeds and York? The first difference will probably be a lack of a cycling facility (cycleway) in Leeds, and, more fundamentally, cycleways in Leeds are not well connected, but fragmented. Figure 5.9 shows the diagrams of overlapped cycleways (green line) and actual routes (brown line) in York and Leeds. A fairly large number of the actual routes in York are overlapped with the cycleway, while a few of the actual routes in Leeds are overlapped. The figure shows that the cycleway in York is relatively well connected and stretched in radial from the centre. On the other hand, the figure shows that there are a few fragments and scattered sections of cycleway to the north and central areas in Leeds. Although the cycleway on the bottom-right side is well connected, it seems that it is not popularly used as it does not head for the city centre. In other words, the cycleway in Leeds seems rather far away from the actually demanded routes. This is partially a matter of where cycleways should be built and because the cycleway in Leeds may not be useful for transport purposes.



York Leeds

Figure 5.9 Cycleway and Actual Routes in York and Leeds

5.6 Conclusions of the Chapter

The analysis using actual route data and route evaluation data together answers the following research objectives:

Objective 3*: Investigating the features of the actual routes that cyclists currently use*

Sub-objective 3-1: Investigate the characteristics of the actual routes

Sub-objective 3-2: Investigate differences in the characteristics of the actual routes by trip purposes

The analysis was carried out by comparing paired routes as well as statistical analysis with route evaluation data for the actual routes. It proved that there are cyclists who chose their routes under different criteria and purposes for different trip purposes. Furthermore, cyclists had alternatives or variations for the same origin and destination for the same purposes. The reasons that they had such alternatives were also revealed.

Cyclists in Leeds chose their routes for minimising time basically and had alternatives for more relaxed ridings whereas cyclists in York had good routes for daily trips, but their alternative routes were more like emergency spares. The differences in the quality of individual routes were not significant within the same city. However, the quality of route features in York was much better than the quality in Leeds, particularly in terms of cycling facilities. More importantly the perceived quality of female cyclists towards route features had significant gaps between Leeds and York.

The approach using route evaluation and comparisons with paired routes were half successful and half failed. The approach identified a few differences in route choice criteria and route features and showed why cyclists chose one over another. However, it was hardly possible to know what the routes were like, and too many features were considered. However, the approach of analysis found the reasons or factors for the choices.

The findings are summarised as follows:

Cycling behaviours

All the results show that cycling activities were more active in York than Leeds. Cyclists in York made more frequent trips by bicycle, especially women and for personal purposes, whereas cycling in Leeds was more concentrated on commuting and dominated by men. These differences indicate that women and personal trips are key targets for increasing cycling uses.

- Trip distance and time and cycling speeds were shorter and slower in Leeds than York.
- More cycling activities were made for personal purposes such as visiting.
- Cycling trips were made more frequently in York than Leeds.
- Female cyclists in York cycled longer distances on average than in Leeds.

Characteristics of actual routes

The comparisons were made in 3 ways: between to-work routes and back-home routes, between main routes and alternative routes and by trip purposes including back-home, commuting and personal.

In comparisons between to-work routes and back-home routes:

- Cyclists in Leeds took an advantage of going downhill for to-work routes.
- Back-home routes in Leeds were chosen for 3 key reasons:
  - ✓ Cyclists took a detouring route of a fairly longer distance for the better environment and more comfortable and pleasant rides.
  - ✓ Cyclists took a different route for relative less hilly routes as using the to-work route in the opposite direction was hillier than back-home routes.
  - ✓ Cyclists were actually forced to choose a different section of a route to visit a certain place such as a shop or one-way system.
- Cyclists in York chose different back-home routes from to-work routes for the convenience of crossing a junction.

In comparisons between main routes and alternative routes:

- Cyclists in Leeds had alternative routes for pleasant and comfortable cycling with better scenery away from roads and traffic

- Main routes in York were better than alternative routes. However, cyclists had alternatives for two reasons:
- alternatives were more reliable and mainly followed the road network of the city
- Cyclists in York had alternatives to visit a certain place. This is similar to the reason of back-home routes in Leeds.

In comparison between actual routes in York only by trip purposes:

- No difference was found between commuting routes and personal routes
- Back-home routes were chosen for pleasant and comfortable riding while the routes for personal and commuting trips were chosen for minimising trip distance and time.

Quality of Actual Routes

The quality evaluation data provided a few key difference between Leeds and York and male and female.

- Safety was relatively a problem with the routes in both Leeds and York.
- Actual routes in York had better quality route features than the ones in Leeds.
- Cycling facilities had the largest gap in the quality evaluation, as the quality of cycling facilities in York was better than Leeds.
- Female cyclists in Leeds especially gave a low score to the quality of cycling facilities.
- Female cyclists in York were much more satisfied with the quality of cycling routes than not only male cyclists in York but also female cyclists in Leeds.

Chapter 6 Analysis of Interviews

6.1 Introduction

In the previous chapter actual route data was analysed that identified different patterns for cycling routes by trip purposes. This chapter presents the analysis results of the interviews with the actual routes used in chapter 5. The chapter probed reasons for the choices of cyclists' current routes and opinions about route features.

The key reasons identified are presented in section 6.2 and the opinions of cyclists about route features follow in section 6.3. Discussions and conclusions are presented in sections 6.3 and 6.4 in order.

The following sections present firstly the reasons why cyclists use their current routes and, secondly, the route features which influence those reasons.

Information about the participants and schedules for the GPS survey and interviews are presented in Appendix 6.

6.2 Why do you use this route?

Figure 6.1 shows the reasons identified for cycling route choice from interviews. In Leeds, there were one or two dominating reasons for each route type except for variations, while in York it was relatively difficult to extract one or two dominating reasons for each route type. In total, 15 reasons in Leeds and 19 reasons in York were identified.

Figure 6.2 clearly shows frequencies of the identified reasons for route choices as a whole in Leeds and York respectively. Some of them were frequently mentioned during the interviews, whereas some of them were mentioned once or twice. The key reasons for route choice were Quickest, Greens, Riverside, One-way system and Gradients. Among them, Riverside was especially an important reason for the cases in York while Gradient was important for the cases in Leeds. The reasons were not always independent of each other but often related; for example, poor weather in Leeds was related with Greens, and Flood in York was related to Riverside.

Route type	To-work	Back-home	Commuting	Personal	Business	Variations	Alternatives
Reasons In Leeds						No reason(1)	Choice(1)
						Easy way(1)	One-way(1)
						In hurry(1)	Quickest(1)
		Safety(1)				Escort(1)	In hurry(2)
		Utility(1)				Gradual uphill(1)	Poor weather(3)
	Slow traffic(1)	Gradual uphill(2)				Greens(1)	Utility(3)
	Balanced(2)	Greens(3)	Greens(1)	No alternative(2)		Choice(2)	Gradual uphill(3)
	Quickest(12)	One-way(5)	Quickest(10)	Quickest(6)		One-way(2)	Greens(8)
Reasons In York	Quickest(4)	Riverside(2)	Riverside(2)	Quickest(10)	Quickest(3)	One-way(4)	Flood(3)
	Riverside(2)	Quickest(1)	Greens(2)	Riverside(4)	Riverside(3)	Escort(2)	Quickest(2)
	Safety(2)	Greens(1)	Quickest(1)	Greens(4)	In hurry(1)	Utility(2)	Greens(2)
	Greens(1)	One-way(1)	Balanced(1)	Utility(3)	Avoiding junction(1)	Easy way(1)	One-way(2)
		Personal security(1)	Flat(1)	Familiarity(2)	No alternative(1)		Accompany(2)
		Cycle lane(1)		One-way(1)			Escort(1)
		No reason(1)		In hurry(1)			Utility(1)
				Accompany(1)			Balanced(1)
				Flood(1)			
				Pollution(1)			

* (count)

Figure 6.1 Reasons for Route Choices in Leeds and York by Route Types

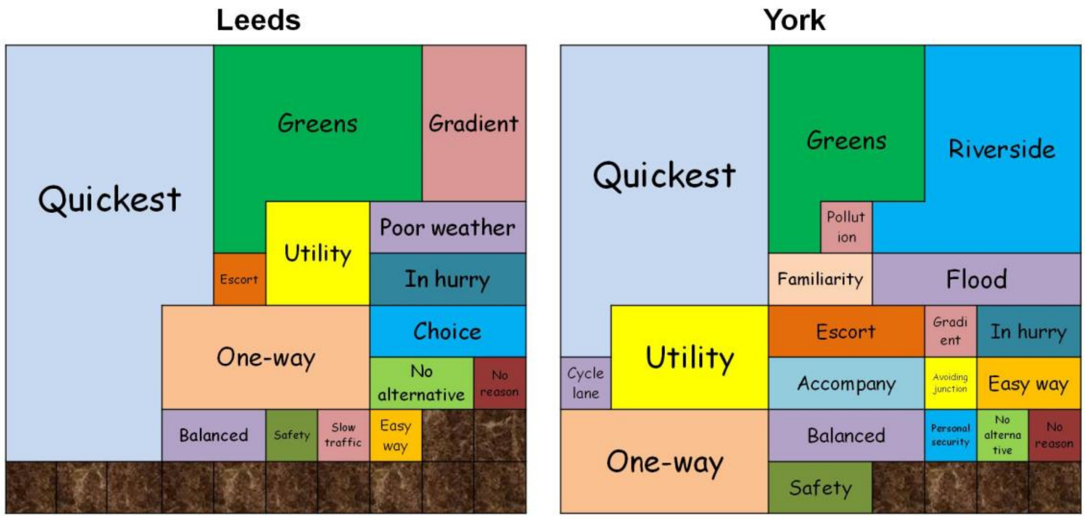


Figure 6.2 Frequency of Reasons for Route Choices in Leeds and York

The key reasons identified are presented in the following sections.

6.2.1 Theme 1: Quickest Route

The most important reason for route choices regardless of city was which one was the quickest. This is especially true in Leeds, as it was an almost dominating reason for choices regardless of route type, except for returning home. However, in York, although quickest was also the most important reason for route choices, it was not the single dominating reason for cycling routes.

The thesis suggested 'quickest' through the chapter rather than 'shortest' or 'fastest', which are more common in the previous studies. This is because cyclists did not simply choose the shortest routes in time or distance. A few previous studies confirmed that the actual routes are neither fastest (Howard and Burns, 2001; Raford et al., 2007) nor shortest (Altman-Hall et al., 1997; Howard and Burns, 2001; Menghini et al., 2010; Raford et al., 2007). Both trip time and distance were not satisfactory in explaining cycling route choice because there were a variety of other factors influencing the choices.

Interviewees expressed "quickest" in mixed ways, such as most direct, fastest, straightforward etc. The expressions were mixed in time and distance as well. Evidence of mixed uses of time and distance was found in the route quality evaluations. Cyclists in Leeds gave a score of 5.09 for minimising distance and 5.15 for minimising time, while in York it was 5.62 and 5.72 for each. There was not much difference in the scores between time and distance, but it was slightly more influenced by trip time (Sener et al., 2009). From the cyclists' points of view, the quickest route is the one satisfying what cyclists want from a route within the available time, so it was close to the fastest routes.

However, the meaning of "quickest" was quite complicated because this word included many different aspects within it. Quickest could not be explained by a single element. Figure 6.3 shows what internal factors the quickest routes had through the interview contexts. Most of the elements were common in both cities, while a few of them were only mentioned for the cases either in Leeds or York.

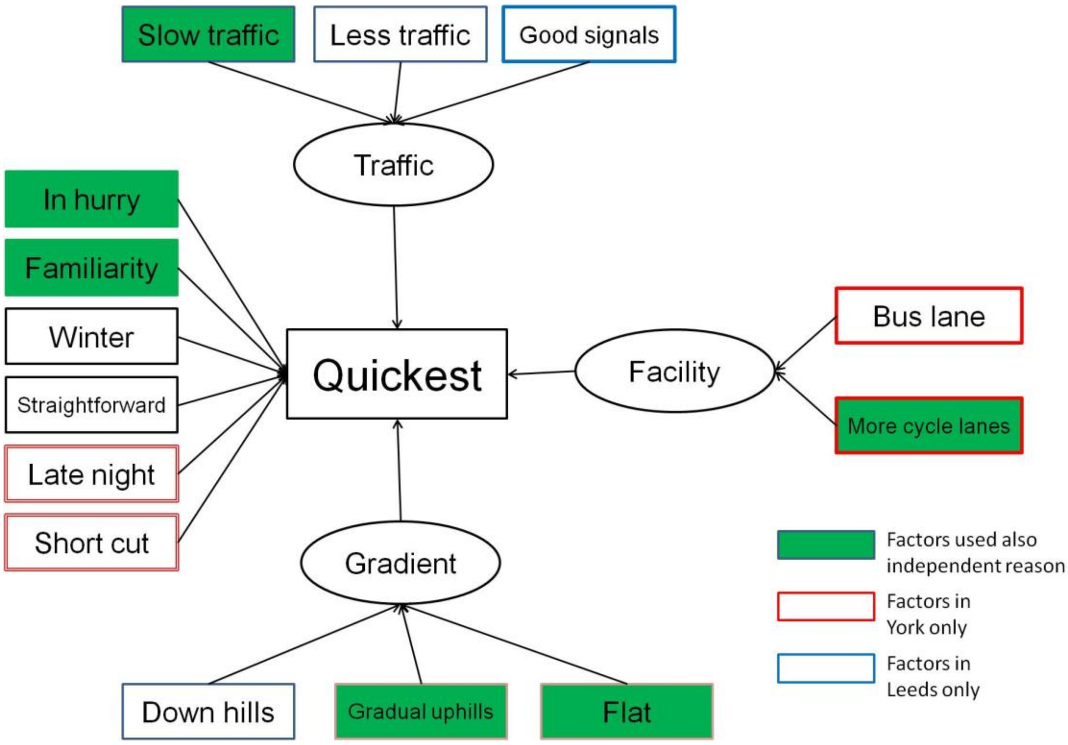


Figure 6.3 Elements related with Quickest Routes

Traffic, gradient, and facilities were 3 key factors which made a route the quickest option. Slow traffic movements and less traffic volume on roads made cyclists feel that the current routes were the quickest ones. This is obvious as such traffic conditions give more chance to accelerating cycling speed with less worry or paying attention to traffic movements. However, heavy traffic volume makes vehicles slow down, and if there is room for cycling, a stationary traffic situation seems easier for cyclists to pass through.

> "Going into work in the morning, there's **normally stationary traffic, but there's room to go past**, so I normally go into work on the main road." (L6)

Stationary traffic or slow traffic also made cyclists feel safer than normal situations.

> "it's a main road and a busy main road with some busy junctions, **but I actually don't feel unsafe because it's peak time, the traffic's not really going fast**, so even though it's very busy, it's alright." (Y15)

Good traffic signals are a factor in making the quickest routes, as cyclists could stop less frequently at a junction. Therefore, consequently cyclists could quickly arrive at a destination.

> "I think when I go to university **it feels much quicker** in the think it's probably because the **traffic lights are set up in a way where I can travel quite quickly** whereas when I'm going from university back home there are some quite inconvenient traffic lights, […] so you have to stop quite often." (L24)

The previous studies found that cyclists tended to avoid traffic lights and stop signs to reduce times for stopping and re-accelerating (Fajans and Curry, 2001; Stinson and Bhat, 2003). However, Aultman-Hall et al. (1997) found that the actual route had more traffic lights than the shortest routes. This means that although traffic lights are a negative factor in route choice, if there is a traffic light with an optimised signal sequence which allows cyclists to less frequently stop at junctions, that signal provides a positive impact on the choice. Therefore, more optimised traffic signals for cycling on roads make cycling routes more attractive for cyclists who aim to arrive quickly at a destination.

In terms of gradient, there was a difference in the attitudes between Leeds and York. The geography of York is flatter than the one of Leeds, so gradient related comments in York were rarely found during analysis. Furthermore, there were fundamental differences.

In York, a simply flat route was chosen and the gradient was hardly a problem, whereas in Leeds downhill was a beneficial factor when it was available along the route. Using downhill routes makes cyclists arrive a destination quicker with faster speed and less energy. However, if cyclists use the same route on a return journey, the gradient becomes a big barrier to cycling. Therefore cyclists in Leeds chose less hilly routes and ones that went gradually uphill as an alternative. Furthermore, if cyclists feel that the gradient was still hard, they simply walked rather than riding. These choice strategies by cyclists in Leeds were also identified in the analysis of actual routes in chapter 5. As shown in the transcript below, cyclists knew what they needed to pay for less uphill routes.

> “I choose to do it that way round because on the way in, there are a lot of steep, […] but it’s really steep on the way back, whereas if I go home this way, it’s a sort of a **gradual gradient**, but the traffic is obviously significantly worse on the A660, but that’s **my payoff**.” (L3)

In terms of cycling facilities, cycle lanes and shared bus lanes were found as factors influencing the quickest routes, but only in York. Bus lanes and cycling facilities give a positive influence to determining whether or it is a quicker route. However, the influence was very limited. Through the interviews for individual routes, bus lanes and cycling facilities (or cycle lanes) were rarely mentioned by candidates. For example, participant Y16 mentioned that the route was direct and there were cycle lanes along, but it was not clear that cycle lanes actually made using the route quicker.

> “This is **more direct** and there are **marked cycle lanes** all the way along.” (Y16)

On the other hand, according to the answers to the separated questions about cycling facilities and bus lanes, cyclists recognised that cycling facilities will help make trips quicker. More details about the attitudes towards cycling facilities and bus lanes were presented in sections 6.3.2 and 6.3.3.

When cyclists use the quickest routes

Cyclists usually chose the quickest routes for going to work. However, there were several reasons to choose the quickest routes, such as hurrying, winter and cycling late at night. Several cyclists indicated that they had alternative routes when they were in a hurry to a destination, especially for personal or business trips in York. Therefore, allowed time was an internal factor for choosing the quickest routes.

> “I do this route **when it’s dark** or if **I need to be really quick**. […] I’ve got various different ways […] it is the fastest, it’s only 20 minutes.”. (L2)

In the winter season, cyclists tended to choose the quickest routes, especially along main roads. This is basically because of poor maintenance along other alternative routes, especially off-road ones. Roads are relatively well gritted even in snow, so using the quickest routes often means riding along main roads rather than residential or off-roads, and this means the shortest in actual trip time.

There were a few factors that make cyclists feel a route was quickest, including familiarity, straightforwardness and the presence of a short cut. For example, if cyclists were familiar with a certain route they felt it was quicker. As they know the route features, such as junction signal sequences, they do not need to waste their trip time with any other interruptions or unexpected elements. In addition, routes with available short-cuts were treated as the quickest route, as such a route provided extra savings either in time or distance.

Familiarity was a fairly psychological element, and cyclists felt that a route was shorter regardless of the reality. They simply felt the route was quicker as they already knew it well. This was found in an interview with a case in York.

> "[…] I had that route in my head and **I was familiar with it,** and **now I have realised that this route is too long**." (Y3)

A few participants simply chose their routes because they had already known them fairly well despite the routes having rather poor conditions.

> "[…] it's just bumpy, a footpath and a really rutted road […], it's just habit because **I used to walk that way a lot** when I had small children, I used to go and visit." (Y12)

6.2.2 Theme 2: Greens/Riverside/Poor weather/Flood

Greens, Riverside and Flood were other very important reasons for route choices for cycling. Greens mean using routes away from traffic, such as parks. Greens were a factor for the both cities, while Riverside and Flood were factors only for York. Fundamentally, Riverside would be a part of Greens, but using riverside paths had different meanings from using green areas in Leeds.

Figure 6.4 shows the elements which influence the choosing of Greens. Greens routes were frequently used during summer seasons and in good weather. Extra time available was important in using greens routes, so cyclists used them as an alternative rather than routes they used mainly. In Leeds greens routes were used popularly for the trips going back home, but when there was time, cyclists also used the routes for trips going to work.

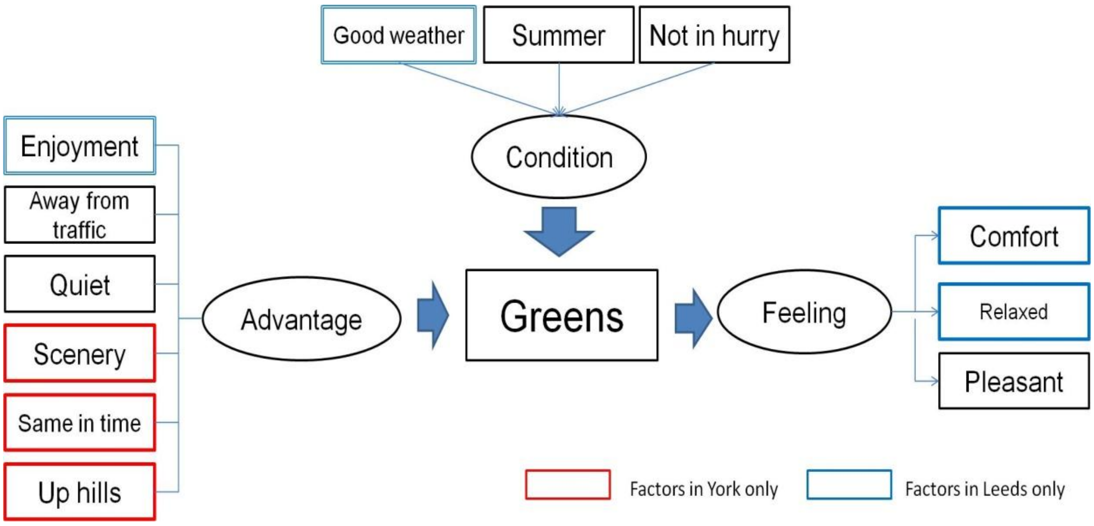


Figure 6.4 Advantages, Conditions and Feeling from Greens Routes

The most important advantage of using green routes was that they were away from traffic. It indirectly indicates that riding with traffic is a very stressful activity. Enjoyment, quiet, good scenery etc were also advantages. It was found that cyclists felt comfortable, relaxed and pleasant when they used greens routes. In other words, cyclists definitely used greens route to remain stress free, to keep away from traffic and for more leisure-like trips.

> "Well, it **depends on how much time I've got and what the weather's been like** […] you can cross over there and then you can be in the park here, this is nice, it's trees, **it's a nice gorge, there's a stream there, it looks lovely.** In spring you've got the flowers coming out, you can hear the woodpeckers. They do say there are deer in here. You know, it's a kind of a nice sort of nature ride actually, […] that is the most **scenic route** and you see the lake, which is nice." (L11)

However, In Leeds, poor weather was a barrier to use greens routes and a reason to choose alternative routes to Greens. When weather was not good, it was difficult to use routes in park areas as they became muddy or too icy.

Therefore cyclists rode along main roads, which were generally well maintained.

However, the findings in York seem a little different from Leeds, even though basically both cities shared many common elements. In York, greens routes were popularly used as the main ones, but mainly for personal trips. Personal trips are generally not as much of a hurry or less hurry than commuting trips in the morning. It may be also more influenced by short trip distance and time in York than in Leeds. This can be supported by an element of ‘Same in time’ in York. Participants using greens routes expressed that there was no or not much difference from using other available routes in trip time. Therefore this makes cyclists in York choose green routes rather than any other routes and accept a small difference in trip time for using them.

> “I mean I’ve probably got four or five different routes, which all offer **very equivalent journey times and journey distances**, but this one takes me down […] To **cycle through the Minister** on your commute to work in the morning is **quite nice**.” (Y11)

Another interesting point in York was that some of participants actually preferred greens routes as they went uphill. They thought that having parts that were uphill would be good for their health and exercise. This is caused by the flat geography through York. Therefore riding along uphill routes was another enjoyment in cycling, but this was only because they live in York, which is flat.

> “Well **there's a steep little hill**, **I like hills actually**. Well I like them. [...]. **York is very flat**. Do you live in Leeds? Well it’s nothing like Leeds, I might not like them so much if I lived in Leeds.”(Y4)

In terms of Riverside routes, the characteristics here are fairly different from greens routes. Figure 6.5 shows elements which influence the characteristics of riverside routes. Riverside routes share several common factors with green routes, such as being away from traffic and quiet. Cyclists in York also mentioned being ‘safe’. which meant safe from traffic.

However, the key difference between riverside routes and greens routes was that they were used as the main routes rather than alternative routes regardless of trip purposes. This is due to the location of riverside routes in

York, which pass through the central area of the city. It was possible that riverside routes also provided an advantage in trip time.

"[…] because I get to go along the river. I think it's the one I choose when I'm late, so I think **it's the shortest in time**. I don't know about distance. I like the river part." (Y3)

However, there is also an opposing opinion that says riverside routes were used only when not in a hurry, like greens routes.

> "This is nearly all off road, […], because its nicer, but I **wasn't in a hurry**, I had plenty of time." (Y1)

These differences may depend on the closeness between riverside routes and the origins or destinations of trips.

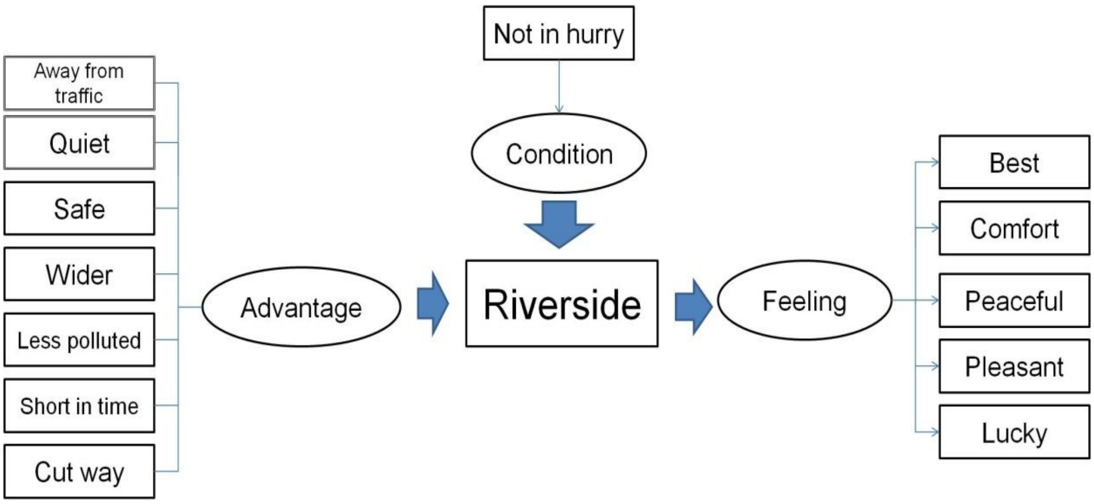


Figure 6.5 Advantages, Conditions and Feeling from Riverside Routes

Riverside routes were relatively less influenced by seasons and weather conditions, except for when it was flooded. When there was a flood, the routes were closed for safety and it took some time to remove mud and other waste. In that case, cyclists used alternative routes along main roads. Therefore, flooding was an important factor for using alternative routes. In the analysis of actual routes, cyclists in York chose an alternative one because their main routes, which were along the riverside, were less reliable. Flooding was the reason for this. So cyclists in York used riverside routes as the main options for cycling trips, and when the river was flooded they used a route on the road network.

> "It's **not necessarily reliable** because when t**he river floods you can't ride along there**. there's another route as well." (Y16)

Despite limitations due to the small sample sizes, the analysis found interesting findings in choosing greens route or riverside routes with gender, (Table 6.1). Male cyclists tended to utilise greens routes more, as 50% of male cyclists had a greens route(s) while less than 30% of female cyclists had them. On the other hand, female cyclists used riverside routes as much as male cyclists. This indicates that using riverside routes is much easier than using riverside routes for female cyclists. The reason was not found through the analysis, but this will be also related with the location of riverside paths, which are close to the central area of the city, and this will provide advantages in safety from traffic and trip time together.

Table 6.1 Counts of Cases Choosing Greens and Riverside Routes by Gender, Confidence Level and Criteria-based Types

Category	Sample Size		Greens		Riverside (York only)
	Leeds	York	Leeds	York	
Males	14	12	7	6	7
Females	10	11	3	2	5

6.2.3 Theme 3: One-way system

The one-way system acted as a reason for route choices in both Leeds and York. However, again, the roles of one-way system were slightly different in each city. In Leeds, a one-way system was a factor in choosing a different route for trips back home than from trips going to work because cyclists could not use the same route in the reversed way. Therefore cyclists were actually forced to choose a different route. The one-way system was not welcomed by cyclists, as it often forced them into taking a longer route going around. Therefore the one-way system will be effective for controlling motorised traffic but not for cycling, and some cyclists may ignore one-way system and ride in the opposite direction.

> "It's quite **a crazy place to get through Leeds. The roads are all one way. It just doesn't make any sense to me**. I guess you've only got so much space."(L15)

> "I normally go this way […] because there's no easy way to get down, you have to walk your bike. It's one way in the other direction, so you can't go down it that way. **Lots of people do, but it's illegal** because it's one way in that direction." (L6)

In York, one-way system acted as a factor for having variations rather than making a longer round trip. Cyclists in York could join their main route soon after rounding the one-way section. Another point with York was the pedestrianised areas for certain times of day. The pedestrianised areas acted similar to the one-way system and cyclists needed to ride around them at certain times.

> "You're not allowed to cycle through here in the day. This is the pedestrian area in York. I think that's, is that Stonegate? So, yeah **all of town is pedestrianised, I think it's between 10 and 6 you're not meant to cycle.**" (Y15)

Te one-way system was a rather unexpected finding; however, it obviously influenced cyclists' route choices. In Leeds, the one-way system was the most frequently mentioned reason in trips coming back home (5 out of 12 cases) and also mentioned for variations (2 cases). In York, it was the most frequently mentioned for variations (4 out of 9 cases), and it featured in 2 cases for alternatives and one case for back-home and personal routes (see Figure 6.1).

The characteristics of back-home routes and variations to main routes are different each other. Back-home routes are completely different, or at least major parts of the routes, are different from to-work routes, while variations have only a small different sections from base routes. This indicates that cyclists in York can easily re-join their main route after passing a one-way part, while cyclists in Leeds do not re-join their main route after passing a one-way part or can't re-join. It is unsure in this study why there are these differences. However, the one-way system has more of an impact on route choices in Leeds, and cyclists there dislike the one-way system.

It was difficult to find academic studies dealing with a one-way system for cycling. However, practical field already recognised that this system gives a disadvantage as it can force cyclists to take a longer route (CTC, 2013). As a solution, allowing a contra-flow in one way roads is encouraged (DfT, 2008c).

6.2.4 Theme 4: Gradients

Gradient was found as a factor for route choices in Leeds only. Gradient in route choice meant not only downhill but also uphill, especially gradual uphill. As shown in Chapter 5, cyclists in Leeds chose gradual uphill instead of steep uphill: choosing the second over the worst. It is consistent with the findings of a few studies that cyclists preferred less steep routes (Menghini et al., 2012; Broach et al., 2012; Hood et al. 2011)

Downhill acted as one of the elements in creating the quickest routes. However, it became a disadvantage for trips in the reverse direction. Leeds is a quite hilly city where the central area is lower than surrounding area. So cyclists in Leeds chose routes that went gradually uphill which cyclists could afford to cycle along. Gradual uphill was also a factor for the routes in coming back home or alternatives to main routes.

> "The uphill bit (in To-work route) **is very steep**. **It's a short, sharp, steep climb, which I just can't do**. It's a much more gradual climb, **it's a very steady climb. I mean I can do that on**." (L12)

Gradual uphill seemed slightly more important for female cyclists than male cyclists, but there was no clear reason for this. The analysis with only the cases having a gradual uphill slant showed that female cyclists were more sensitive to hilliness than males. However, the analysis including the cases with less hilliness, which was not a main reason but was one of the factors that showed that there was no significant differences in choices by gender. Table 6.3 shows the results of the analysis. So it can be assumed that cyclists tended to change routes from being steep uphill to gradual(less hilly) if there was an alternative regardless of gender.

Table 6.2 Cases Choosing Gradual Uphill or Less Hilly Routes by Genders in Leeds

	Gradual uphill	Less hilly	Total
Male (14)	2	4	6
Female (10)	3	1	4

6.2.5 Theme 5: Utility, Escort, and Accompany

Utility means visiting a certain place with a purpose, such as shopping. Most cases in Utility involved shopping, but there were other activities too. Escort was an activity involving taking a child to school and any other activities or otherwise picking them up. Accompany was cycling with someone else together. These three reasons were found in York more frequently than in Leeds.

Utility and escort are chained trips, so there are other main trip purposes. Therefore cyclists choose an alternative route or a variation from their usual routes. Accompany is also not the main trip purpose but also not a chained trip, just with someone else.

The most common reason for utility was shopping; for example cyclists went shopping on the way back home. This reason is not much different for the quickest routes in terms of the characteristics of the routes, but cyclists needed to choose the best route to visit two places continuously.

Escort and accompany have a different characteristic as they cycle with someone else. Therefore, depending on the person who cyclists carry with or cycle together, they need to consider an extra factor such as safety. For example, when cyclists needed to take their child into a certain place, such as school, they tended to choose a safer route. The below transcript clearly indicated this tendency.

> "**I took my daughter to here** for her childminder and then I set off to work that way, **which is a bit of a longer route, but all this is off road**. **This is a marked cycle route**. (Y16)

An extra factor which cyclists needed to consider for a route also depends on who the cyclists accompany, especially the cycling ability of the other person. For example, in the two transcripts below in order, when a cyclist cycled with a friend, the route was for fun, while when the other cyclists cycled with his wife he chose the route for the wife's convenience and comfortable riding.

> "Just for a change. Sometimes **a change is just nicer**. […] I have a friend who always uses this route every day. […] I **cycled home with him** that day. […] sometimes I just do it **just for fun**, but it's not really one I use frequently." (Y2)

> "I suppose the other factor to take into account, because **I'm cycling with my wife**, we're cycling much slower. The reason why we go this route is because it's **more convenient for her destination**, so it's best for both of us. We cycle much slower, therefore you do **feel more comfortable**." (Y11)

6.2.6 Theme 6: Safety and Personal Security

Only one case in Leeds and two cases in York chose safety as a reason for route choice. This was an unexpected result as safety is an important issue with cycling. Safety was highly related with traffic on roads and a "safe route" meant basically being safe from traffic. Therefore routes with less or slow traffic were safe routes. In addition, this was related with residential roads in which there was relatively less traffic volume and slower traffic than main roads. However, in most cases in the analysis of interview data, safety was not a main reason but a matter coming together with traffic issues.

> "This is nearly all off road, […] Safety and pleasance. Probably **safety because you don't have to worry about traffic**, it's relaxing." (Y1)

> "Because not all of it is on a main road, some of it is **designated pedestrian and cycle**, […] I'd say **half my journey doesn't involve cars and buses** particularly on a morning so I think **it's the safest**." (Y5)

Personal security is a quite interesting reason in both cities, and it is one that was not clearly pointed out by cyclists for cycling routes. Many participants recognised that there were certain areas where potential hazards existed, but they also thought that they would be okay. Only one case in York indicated that a cyclist chose the current route because of personal security matters. The cyclist changed a previous route to the current route after she experienced trouble with young boys. Furthermore, she felt more vulnerable as she is a woman.

> "It's just that **I used to go a different way which was an off way route** which was traffic wise a lot safer**. It was a gang of boys** [….] most days we just happened to meet, and then **they started trying to knock me off with stick, branches through my spokes, it ended with them trying to grab my bag, I always had it tied in but at that point I got the police involved. ultimately I'm a woman alone.**" (Y9)

It seems that cyclists are rather confident even with hazardous areas before they actually experience any trouble. However, after experiencing issues personal security becomes a far more important factor for route choice and lead to them changing their route.

6.2.7 The others

There were many other minor reasons for route choices, including Balanced, Pollution, Easy-way, etc. However, the influence of these reasons was limited in route choices. All the minor reasons are presented in the section.

Balanced routes

Balanced means that two different reasons were optimised together; for example short in time and safety were both considered equally for a route.

In Leeds, balanced meant Safety and Shortest in Time, while in York, balanced meant Fast and Exercise. Therefore the cases in Leeds were more related with safety matters, whereas the cases in York were more related with personal enjoyment during cycling.

However, in terms of the case in Leeds, safety would be already considered by other cyclists too because traffic is the main source of safety matters with cycling. However, the interviewees just mentioned safety as a reason and the others did not.

Choice

Choice as a reason for route choice means that cyclists chose a certain route based on traffic conditions at a certain location. For example, a cyclist decided to go straight at a junction because turning right there was not easy. Therefore this reason was rather made by instant judgement considering traffic conditions.

Pollution

Pollution was not considered as a reason for route choice at the beginning of the study, and it was also not mentioned at all in the interview except for only one case in York (who strongly expressed the problem with air quality in that city). Although she pointed out air quality problems and provided evidence, most cyclists do not recognise that as a problem (which she also pointed out).

> "The air quality here is awful. **The main problem in York is air quality**. Here, very bad air quality. second worst in Britain for Nitrous oxides,

> yeah. It's poisonously bad, it's poisonously awful here. **Most people don't know about the air quality problems**." (Y17)

Traffic, junction, cycle lanes

Some of the reasons, such as slow traffic, avoiding a specific junction and cycle lanes, were considered as main reasons for route choices at the beginning of the study, as well as trip time, distance, safety etc. However, those features were not core reasons but more like the elements which explain core reasons, especially for the quickest routes.

It means that cyclists may not simply change or choose their routes just because of improvement of traffic conditions, new cycle lanes or improved junctions.

> "I think **it would be nice** if the council thought about the main...where people want to cycle, so what are the desire lines of cyclists. […] you can't cycle south from the university to the railway station without taking a massive detour in one direction or the other, or getting off your bike, but surely that's an important desire line for cyclists […]. **It would be nice** if the council...they clearly think about what the desire lines are for cars and build things to suit them, […]." (L6)

6.3 Opinions of Cyclists to Route Features

In the following sections we will present what cyclists think about route features, including traffic, cycling facilities and bus lanes, junctions and advanced stop lines, as well as cyclists' expectations for improvement of cycling in order.

6.3.1 Traffics

The results from the questionnaire and route evaluation data indicated that traffic was a main source of problems for cycling on roads. Although traffic matters were not mentioned as a primary reason or factor for cycling route choice in interviews, traffic was mentioned as an important element in reasons for route choice.

It was found that there were differences in thoughts of cyclists between traffic speed and volume. Table 6.3 shows a summary of the responses regarding traffic.

Table 6.3 Reasons that Traffic Speed or Volume is Important

Main theme	Reasons for importance	Leeds (Count)	York (Count)
Speed	More traffic, speed down	2	6
	Manoeuvre	-	1
	Big vehicle	1	1
	Feeling dangerous	4	6
	Time to judge	2	1
	No reason mentioned	1	-
Volume	More stress	1	2
	Manoeuvre	2	2
	Environment	1	-
	Consistency	-	1
	Watched out	-	1
Others	Depend on roads	1	-
	No problem at all	1	-
	Matter is space	1	-

Overall, more cyclists indicated that traffic speed was more important than traffic volume in regards to route choices. The main reason that traffic speed was more important was that cyclists felt high speed traffic was dangerous. One of the participants in Leeds described that he felt frightened, especially when there was a large difference between car speed and cycling speed.

> “Speed. If it’s too fast, it just **feels scary**, you know, if people **come past you**. The limit is 70, people don’t do 70, **they do 80 or 90**, whatever. And when you’re doing 15-20, **it’s scary**.” (L13)

The reason that high traffic speed is a problem is that there is a lack of time for making judgements. Interviewees pointed out when cars were travelling at high speed they would not have enough time to notice a cyclist around them or react to sudden happenings. This can be applied to cyclists too exactly in the same way as they would not have enough time for do something against approaching cars.

> “I think heavy traffic volume slows the traffic down and their awareness time of you increases, but **when they’re going fast, it reduces the amount of distance they have to react and also with yourself**.” (Y11)

Another matter with high speed was linked to big vehicles like lorries. When big vehicles pass by at fast speed they cause cyclists to feel more at risk than with other vehicles. There was a problem with finding a gap among vehicles to manoeuvre. When traffic was moving fast, it was difficult to find a proper gap to cross a road, so cyclists needed to wait for a long time and took more time to arrive a destination.

However, ironically, the reason that cyclists indicated that traffic speed was more important was related to heavy traffic volume and low speed. When there are a lot of vehicles on roads and traffic flow becomes stationary, such a situation helps cyclists ride properly. Relatively slow traffic speed allows for easy moving between cars as well as more safety. This opinion was especially supported in York. So many cyclists enjoyed slow speeds in heavy traffic. The transcript below describes this.

> "Speed absolutely because high traffic volumes actually slow down the traffic and make it easier for the cyclists to be on a level basis with them. […] **I had totally stationary traffic to ride through, totally safe. Yeah, congestion is the cyclist's friend really**." (Y6)

In terms of reasons for why traffic volume is more important, cyclists indicated that more traffic created more stress. Cyclists had higher stress as they needed to pay attention to the many vehicles around them. The transcript below describes this situation:

> "If it's heavy volume of traffic, it feels **a bit relentless and you've got to watch out for more things maybe happening**. If it's just a few people going fast, you can usually cope with them, hear them and you know hopefully they won't be going fast right at you. **I think I get more stressed when there's lots of traffic**." (L2)

There was a problem with manoeuvring with heavy traffic. With heavy traffic, it was hard to find enough room to make proper progress or turn. The interesting point with this opinion was that it was the same situation with heavy and slow traffic in the opinions on traffic speed. However, this time some cyclists felt there was more stress or difficulty in finding proper gaps among vehicles. Therefore these completely opposite opinions indicate that there are extra factors with traffic matters, such as the absolute number of traffic volumes, road width or road layouts etc.

> "Well, in the city probably traffic volume because **it stop all the traffic**. Sometimes you **have to get off your bicycle and walk**, you can't cycle because there's too much traffic." (Y16)

There were a few interesting opinions about traffic volume. The first opinion was that more traffic made more pollution while another said that less traffic made vehicles more consistent in their movements. The last one was that it is easy with less traffic volume for drivers to watch out for cyclists. The last one seems somewhat to be contrary to 'Time to judge' regarding traffic speed, but they were different situations: one involved speed being too high and the other involved extremely heavy traffic.

In terms of theme of the Others, there was an interesting opinion. A participant in Leeds pointed out that the matter was not traffic speed or volume, but space from vehicles. This opinion is reasonable. If cyclists can get enough space from vehicles they will feel safer and more comfortable in riding on roads.

> "It all **depends on the space**, **how much space you've got**, and where you've got a bus lane I'd potentially say the volume. If you haven't got any bus lanes or cycle lanes, then I'd say the speed's more of an issue. The last thing you want is people coming past very close to you very fast, whereas **if they're three metres away, it's not so important.**" (L17)

6.3.2 Cycling Facilities

Cycling facilities have various kinds within the means. However, the most important and well-recognised facilities are the sorts of cycling paths. Among them, in general, cycle lanes on roads, segregated cycle paths(or separated cycle lanes) next to roads and off-road paths are generally mentioned in academic terms as well as practical ones. However, there were also participants who did not have preferences on any of them, which means just using ordinary roads or who changing their choice depending on the situations they face. Therefore this study focused on the three cycling path types and roads.

Table 6.4 shows distributions of preferred cycle path types in Leeds and York and the reasons for the preferences. Overall, cycle lanes in Leeds seemed to be a little more preferred than the other types, while more participants in York indicated they preferred off-road paths more than any other types. Strong preference towards off-road paths may be influenced by experience of using the riverside paths whereas a lack of cycling facilities in Leeds may influence the preference towards ordinary roads. This is clear evidence that the available environment in a city influences the choices of routes for cyclists.

The important point with cycling facilities was safety. Safety was not frequently mentioned as a reason for route choices in section 6.1. However, safety was one of main reasons that cyclists wanted cycling facilities regardless of type. This proves that cyclists felt safer with cycling facilities even though the facilities are not fully separated from traffic. The following transcript supports this view.

> “Well, in terms of commuting on the road, **what would make it safer would be more cycle lanes**. […] if you’re cycling, you’re so vulnerable on a bicycle […], so I think **cycle lanes would definitely improve matters**.” (L9)

There were also differences in reasons for preferences for each type of cycling facility. Cyclists preferred cycle lanes due to practical aspects, while off-road paths were preferred due to pleasant riding environments.

Cycle lanes were preferred due to practical aspects such as being well maintained and speedy commuting in both cities.

> “I prefer to get me around I prefer the cycle lane on the road. From what I mentioned before you tend **to get better lighting**, you are **separated from pedestrians** who don't know bikes are coming and they **get gritted in the winter**, cycle paths don't. And I **bizarrely feel safer**.” (Y5)

Table 6.4 Responses in Preferences of Path Types (Multiple indication)

Leeds		Type	York	
Frequency	Image		Image	Frequency
6	Faster, More useful, Safe, For commuting, Visible to drivers	Cycle lanes	Main roads, Most useful, Safe, Better lightings, No pedestrian, Well maintained, Only in York	5
5	Fast/Direct, Safe/Protection, Off from vehicles, Ideal, Psychological advantage	Segregated paths	Direct, Safe, Off traffic & off footpath Well lit	6
5	Easier, Wider, Quiet Ideal, Nicer if quick, Drivers are not looking after cyclists Make most sense	Off-roads	Traffic free, Pleasant, Safe, Riverside scenery, No pollution, Quieter, Attractive	10
5	Impractical cycle lanes Just do, No pedestrians O.K.	Roads	Easy	2
3	Journey by journey OK if no pedestrians	Depends on	Safe, Nice	2

However, there was one interesting reason mentioned in York which overall attitude of people towards cycling influence the preference to cycling facility types. One of the participants there said that cycle lanes were preferred and that the people of York were considerate and tolerant towards cyclists.

> “(Cycle lanes) In York because **York is used to cyclists and cycling**, it’s okay, it’s fine. **People are more tolerant and understanding of other road users, so it’s safe and it’s okay**. I have cycled other places where it isn’t, […] the traffic is heavier and, the provision for cyclists isn’t good, but in York it’s very good.” (Y16)

In terms of segregated paths, reasons for preferring them were basically not much different from the reasons for cycle lanes. However, the main reason was that cyclists are protected from traffic. Furthermore, segregated cycle paths were more beneficial in terms of psychological aspects, as they lead to more comfortable and safe feelings (even though that is not always true).

> “Segregated. I think it gives a **psychological advantage to cyclists**, it probably **doesn't make it safer** that you **feel more comfortable about**. And, no love lost in thought. Probably just make it feel safer even though it's probably not.” (L24)

Fundamentally, cyclists on off-road paths were completely protected by traffic, so off-road paths were preferred because not only are they safe from traffic but they are also nice, quiet and have good scenery. However, cyclists thought that off-road paths were rather idealistic.

> “Well, I suppose **in an ideal world**, I’d prefer the one that’s beside the canal because that would be **quite scenic**.” (L21)

There were also participants who did not like any type of cycling paths and actually preferred roads. They mentioned that purpose-built cycle paths were impractical and road networks were the best way to go to anywhere.

> “I find quite often they’re **badly laid out or they’d be hard to get onto**. There’s one bit just here where if you’re on the road, **suddenly you’d have to take a 90 degree turn to get onto the cycle lane and so it’s just impractical,** I just stay on the road, yeah. I think in Leeds **there aren’t many good bits**, you know, that you would actually use.

There's nowhere that's actually a good sort of designated cycle lane that is intuitive." (L4)

In addition, there were also participants who changed their preferences in case by case. They was actually no specific preference towards cycle path types; however they preferred any cycle paths rather than roads.

6.3.3 Shared Bus Lanes

Shared bus lanes as an alternative to cycle lanes have been introduced in many cities and it is worthwhile finding out what opinions cyclists have about them. More responses were made in Leeds than York, as some of the interviewees had no experience of using shared bus lanes. Table 6.5 shows responses for the question about shared bus lanes.

Table 6.5 Responses for the question for Shared bus lanes

Main theme	Sub- category	Leeds (Count)	York (Count)
Positive	Bus drivers better	4	4
	Better than others	2	2
	Not many buses on	3	2
	More space	3	1
	Feel safer	1	-
	Just O.K	1	1
Negative	Overtaking problem	7	2
	Careless bus drivers	1	5
	Feel unsafe	1	1
	Cultural problem	-	1
Extra concern	Bring taxis to bus lanes	2	-

Overall, more interviewees in Leeds expressed positive opinions on shared bus lanes, while in York positives and negatives were around half and half. However, the opinions about shared bus lanes could not be clearly divided into good or bad. Most cases were somewhat mixed, so in this section what participants think about shared bus lanes is focused on.

In terms of positive opinions, there were no significant differences between Leeds and York. Participants thought that bus drivers were better than other vehicle drivers as they were kind and careful towards cyclists and well trained. The transcript below well describes this opinion.

> “**Bus drivers are professional** drivers, they’re **trained**, they are usually **very careful**. If they’re going to pull out in front of you, they will indicate, the car drivers won’t. They give you plenty of space if they see you coming round, **they’ll give way and let you come round**.” (L11)

A similar opinion to this was that sharing with buses was better than riding with the other traffic. This opinion is also strongly related with drivers’ attitudes towards cyclists. However, this was not the best condition for cycling routes. It was pointed out that sharing bus lanes was just an alternative to separating cycling from traffic.

> “It's ok, it's better to have a separate one but if it's not possible, **it’s better than riding in the main road**. They(bus drivers) are usually very good.” (Y1)

There was an opinion which reflected the actual benefits of bus lanes. Some described how in off-peak times not many buses actually run on bus lanes, so bus lanes are actually quite good to ride on. When it’s empty, even broader spaces are available to cyclists, and this benefit made cyclists feel safer.

> “I think they’re actually fine, especially in Leeds where, on this route, where you perhaps **only get eight or nine buses an hour, you don’t actually have that much interaction with buses, effectively you’ve got a four metre wide cycle lane the majority of the time**. I’d rather have a bus lane than a cycle lane because, you know, **you’re further away from the main traffic**.” (L17)

On the other hand, there were differences in negative opinions between Leeds and York. In Leeds there was conflicts with buses because of overtaking, which was an important concern, while in York bus drivers’ careless driving was an issue.

Overtaking conflict was strongly pointed out by cyclists, especially in Leeds. The transcript below well describes the issues in overtaking. Buses need to stop at a bus stop frequently and they need to move in and out. However, cyclists want to keep riding. Unless cyclists ride very slow or are just very patient, they will attempt to overtake a bus. However, potentially this attempt is risky if a cyclist and bus driver fail to communicate with each other.

> “Well I go quite slowly, and then t**he bus overtakes me, but then there’s a stop**, so I go round the bus and then they go round me again and it seems to happen several times on a bus lane and I feel uncomfortable about that. It’s just annoying that **the bus** is obviously going faster than me, but **has to keep stopping**.” (L2)

The negative opinion about careless drivers in York is described below. The first transcript described how many bus drivers did not look after cyclists while the second described an example of an awful accident. The example of the second shows what would happen and the potential safety issues if a driver fails to notice a cyclist.

> “I have on Fulford Road. I think it's **madness**. Because buses, high proportion of **bus drivers do not look after cyclists**, some big enormous buses next to cyclists seems crazy to me.” (Y19)

> “You know, a friend of mine had a child trailer at the back of his bike, a little thing, and a bus hit it. Fortunately, **it was full of wood at the time, but the bus driver had no way of knowing that**, but he pulled out and as he swung out he hit the child trailer, which was incredible.” (Y6)

The existence of buses itself gave relative fear to cyclists due to its size and frequent stopping at a stop, as well as a moment of losing a sight from cyclists near a bus, which would make cyclists feel unsafe.

However, the negative opinion to drivers is itself rather contradictive to the positive opinion, and so this indicates that drivers are generally well trained but still need more training and to pay attention to cyclists.

An interesting opinion from York was the cultural problem. Although the opinion was not limited to shared bus lanes, the following transcript points out that sharing lanes with buses may not be ideal due to different cultures in Britain from the one in Germany because British people do not tend to obey rules.

> “I just worry about bus lanes, cycles lanes and the **potential for confusion**. Yeah, I think there is a real **cultural problem** in this country with bus lanes and cycle lanes. […] I think it’s potentially dangerous and I believe that, for cultural reasons, […] **in Germany it was absolutely fine, they obeyed the roads, they don’t here. It’s a problem...**” (Y10)

A potential problem in Leeds was that it brings taxis into shared bus lanes. If it is allowed, cyclists need to share buses and taxis all together. One of participants indicated what he actually worried about in this plan and what the problems with that would be. Although the council considers allowing only licensed taxis to share bus lane, there would be the possibility of opening this up to private taxis and making the situation worse.

> “I am concerned that they are going to **open it up to taxis** as well. […] The trouble with **taxis** is they try and speed down and they **do try and get past you** whereas a bus, generally, it tends to be a bit more not fussy because they’re going to stop at the next bus stop, but the taxi is just wanting to make a long distance, so they do try and push past. I think it’ll make it worse, yeah. **They will try and push past you within the lane**. ” (L20)

6.3.4 Junctions

It was found in the questionnaire survey that there was a clear distinction in preferences of junctions by their types. Roundabouts were the least preferred type while signalised junctions were the most preferred. In this section, more details were analysed about preferences on junction types.

Table 6.6 shows distributions of participants’ preferences on junction types and reasons for these preferences. Signalised junctions and roundabouts were located on the far side of each preferred and not-preferred junction. Give-way junctions were less mentioned and cyclists did not seriously take them into account. However, there were still preferences towards giveaway junctions.

Signalised junctions were preferred due to their certainty, which means that traffic signals are fixed so that participants can know clearly when they go or stop. This certainty made cyclists feel safer with them than with the other types.

"Traffic lights because **everybody knows what they're doing** there." (Y22)

Table 6.6 Responses in Preferences to Junction Types and Reasons

Main theme		Sub-category	Leeds (Count)	York (Count)
Signalised	Prefer	Certainty	9	8
		Stopped traffic	1	-
		Safer	1	3
	Not Preferred	Turning	1	-
		Traffic queue	1	-
		Poor signals	1	1
		Unnecessary stops	1	-
Give-way	Prefer	Stop and Look	2	-
		Less stops	3	1
	Not Preferred	Attention to many direction	1	-
		Long stop	1	1
		Unsafe	1	1
		Turn right	-	1
Roundabouts	Prefer	No stop/ Quick	1	2
		With cycle lane	-	1
	Not Preferred	Danger	7	2
		Difficult	1	2
		Overtaken	1	-
		Across lane	2	-
		Not See you	-	3
Depend on			2	3
Pedestrian crossing			1	-

However, signalised junctions also had a few problems. Long traffic queues in rush hour, more frequent stops than give-way junctions and roundabouts, and no proper signals were mentioned as problems in signalised junctions. Signal phases not considering cyclists were a problem; for example cyclists could get enough time to cross a junction.

"They've just put the signal there that is **horrendous**. **It was just going amber as I have passed the lights and I hadn't gotten through the lights before the next set had turned green and the traffic was coming out**, and it was signalised. So **it's not safe, not at all**. I get horns sounded at me on a regular basis […] If you are young gentleman or young lady and got strong legs and a big bike all road bike with thin tyres, I'm not any of them." (L18)

There was a relationship between signalised junctions and advanced stop lines, and advanced stop lines had an advantage that signalised junctions did not. Advanced stop lines are presented in the following section 6.2.5.

> “At the junctions we have advanced stop lines, so there are opportunities for you **to get in the right place to drive off, which at least if you get there were other signals red**.” (Y20)

On the other hand, roundabouts were thought to have a danger when riding with traffic. However, the reasons that participants disliked roundabouts were slightly different between Leeds and York. In Leeds, managing traffic when driving beside or approaching behind was a quite dangerous activity, while in York participants felt unsafe as they were not properly able to see drivers at roundabouts.

> “Roundabouts can be scary if you’re not confident, if you get a roundabout and you’re turning right, you have to go to the inside lane approaching the roundabout, **you have to go inside next to the roundabout and then you have to cut across the traffic and that, again, is scary**” (L5)

> “There are **cars going from every direction you're never sure that they've seen you**. And they are turning all the time it's lots of hazards: Turning, closeness, **they may not give you enough space, they may not see you**. […] roundabouts you have to **rely on other people**.” (Y19)

The two reasons were somewhat similar but different and both are related to risks in traffic. However, cyclists in Leeds focused on interaction between cyclists and drivers, while cyclists in York focused on saying drivers should see cyclists. These are completely different approaches towards seeing a problem.

Although only a few participants are mentioned in the interviews, a benefit of give-way junctions is stopping less at the junction. This is a matter of behaviour, so participants who preferred give-way junctions will simply cross a junction if they think there are no approaching vehicles rather than always stopping and looking.

> “Well, I think if it’s a signalised one, […], **you lose your momentum**. If it’s just a simple give way junction, you can scan the road ahead, you

> can see if there's traffic coming and then you can make the decision whether to carry on or stop. So **there's a bit more choice there**." (L11)

The reason that participants disliked give-way junctions was because they are unsafe and it takes too long to wait for a gap. Making turns and also needing to pay attention to many directions were also strongly related with safety issues.

From the results, we gather that cyclists should always be aware of potential danger when crossing a junction. The reason give-way junctions and roundabouts were less preferred is uncertainty in communication with vehicles. This is especially true at roundabouts as all the traffic and vehicles should keep moving and they have different speeds. It means that when using roundabouts or give-way junctions cyclists are more reliant on drivers' awareness of cyclists. In the case of signalised junctions, as all the vehicles and cyclists stop and wait for a signal for their direction, it is relatively easy to communicate with drivers.

6.3.5 Advanced Stop Lines

During the interviews, Advanced Stop Lines (ASL) were frequently mentioned by the candidates. Analysis found that the opinions on ASL were quite different between Leeds and York. Interviewees in both cities agreed that ASL is useful for cyclists; however, participants in York strongly agreed and only one participant did not agree, while 71% of participants in Leeds agreed, but their agreements were not strong and somewhat just better than a neutral position. Table 6.7 shows a summary of the responses about ASL in Leeds and York.

The most important advantage with ASL was that ultimately cyclists could get better chances to show themselves to drivers as they placed themselves in front of vehicles. The transcript below clearly described this logic among Get the front, Draw Drivers' Attention and Safety.

> "Because you are in the front and **people can see you and you can position yourself** so they can't do stupid things. Even if as a car parked in the green box I'll go and sit in front of the car, and make sure they know I'm there so **it makes me feel much safer**." (Y19)

Table 6.7 Responses for Usefulness of Advanced Stop Line

<table>
<tr><th colspan="2" rowspan="2">Usefulness of ASL</th><th colspan="2">Leeds</th><th colspan="2">York</th></tr>
<tr><th>Reasons</th><th>Cases (Count)</th><th>Reasons</th><th>Cases (Count)</th></tr>
<tr><td rowspan="2">Agree</td><td>Benefit</td><td>Extra space
Draw driver’s attention
Get the front
Easy turning</td><td>15</td><td>Extra space
Draw driver’s attention
Get the front
Easy turning
No fume
Slowing traffic
No interruption by cars</td><td>20</td></tr>
<tr><td>Potential Problem</td><td>Encroached
Through into
Planning</td><td>10</td><td>Encroached
Signal change before getting in</td><td>5</td></tr>
<tr><td colspan="2">May not agree</td><td>Encroached
Cars go round you
Without cycle lanes
Racing traffic behind
Though into
Signal change before getting in</td><td>6</td><td>Encroached</td><td>1</td></tr>
</table>

This point was even more important when HGVs or buses were waiting at signals together. Big vehicles such as buses or lorries could easily fail to notice the presence of cyclists alongside them; however, cyclists could be positioned in front of them in order to show their existence and gain more caution from drivers.

> “Because you aren’t alongside vehicles. **You can get in front of them and they can see you.** Yes, whereas if you’re alongside them and they decide to turn left, they can cut you up and **if it’s a lorry or a bus**, it can be quite dangerous if they’re alongside you and you cycle up alongside them, but **if you’re in front of them, they can see you**. It’s **safer**.” (Y16)

However, a major concern with ASL was vehicles stopping. Such a situation made cyclists hesitant to use it. This occurred usually with taxis, and this matter was more serious in Leeds than in York. The transcripts described this problem more clearly as being stronger in Leeds than York.

> “**I have never seen a police car or a taxi not to go in the ASL**, and they set the example. The buses 50-50, half the time the buses in there, **the taxies on the bus lanes are always in there**. So what's the point. **I think they are a good idea in principle but in practice I think they are worse than useless**.” (L16)

The results show that ASL is useful for cyclists to cross a signalised junction. However, unlikely in York, ASL in Leeds are not well run because many vehicles still stop and wait for signals in the ASL zone. The transcript of L16 clearly describes this problem, and even police cars did not adhere to it. This also clearly indicates big differences in cycling cultures in Leeds and York.

6.3.6 Demands of Cyclists to Improve Cycling Routes

Various reasons for route choice and advantages and disadvantages of the cycling facilities were identified. In this section we found what cyclists thought should be improved for routes.

A summary of the responses is presented in Table 6.9. Cyclists’ demands were divided into 3 main areas: Policy and Planning, Facility and Maintenance.

Table 6.8 Responses for question for demands for improving cycling routes

Area		Leeds (Count)	York (Count)
Policy & Planning	Take it seriously	7	4
	Priority & Enforce	1	2
	Done enough	-	2
	Awareness	-	1
	With pedestrians	1	-
	No great deal possible	2	1
Facilities	Cycle lanes	3	2
	Segregated paths	4	
	Junctions	2	1
	Extra bridge		1
Maintenance		4	6

Most participants emphasised policies and planning for cycling and cycling routes, though what they mentioned was actually not directly connected to route choice. However, some of issues raised during the interviews were indirectly related with route choices. Many of the participants pointed out that cycling should be considered seriously and planning should be made based on common sense. Cyclists thought that current directions in cycling policies, facility designs and route planning are rather away from what cyclists actually want, although some of them agreed that the council is gradually turning in the right direction. The transcript below presented opinions of cyclists about the current problems with cycling related planning and policies.

> "[…]So, my hope is that **what I would like to see from Leeds City Council is actually taking account of cyclists' needs** because **people who develop some of these routes probably haven't been on a bicycle for years** because if they really tried the routes and saw what they were like, I think it would improve the routes because they would see for themselves how difficult it is actually to stick to them at times but I'm not raising my hopes very high because I think Leeds promotes itself as a green city, it likes to, but actually when it comes to it, **in terms of cyclists, I think they're way behind**." (L19)

Another issue with policy and planning is that priority or at least equal rights should be given to cyclists and enforced, making drivers keep the rules.

They pointed out that cycling should be planned as transport means, not leisure.

> "**It doesn't have any sort of priority in the city transport plan** and to me cycling is part of the traffic. We're part of the traffic and yet we're considered as an extra leisure activity, get on your bike and get healthy sort of thing, whereas no, I'm getting from A to B." (Y21)

A more serious problem was that some cyclists did not expect the council to do something to improve the cycling environment. This opinion reflects how what the council had done was not effective or unrealistic from cyclists' points of view.

> "**I don't expect them to improve it.** Although in fact the Otley Road could get worse with the trolley bus they want to put in. I'm not sure how that's going to impact on it. I wouldn't say satisfied, but I just put up with it." (L20)

However, unlike Leeds, some participants in York responded with how there had been a lot of things done for cycling. Cyclists in York had more positive attitudes to the work than the council had done.

> "I actually think **the council have done quite a lot for cyclists and things** like this really busy junction is where the light is, they've got an extra green light for cyclists, **it seems like they've thought about cyclists at least**." (Y15)

The other opinions were to increase drivers' awareness of cyclists. It is an important point, as cyclists thought that the cooperation of drivers was necessary with the increase in cycling use because the consequence of accidents between cars and cyclists can take the lives of cyclists in the worst cases.

> "I think trying to **make drivers aware of cyclists**, you know maybe more signs, you know, which light up and say "**Watch out for cyclists**". The Government want us to cycle more, the city want us to cycle more, the university wants us to cycle more, I think **motorists are the most dangerous thing for us**, so maybe on the back of buses you could have more signs saying "Watch out for cyclists", trying to raise

> awareness with motorists that cyclists are there and if a car driver hits a cyclist, **a car driver will only hurt his car, it could kill a cyclist**." (Y22)

In terms of the theme of Facilities, participants expressed that more cycling facilities should be built because such facilities could improve safety and easy riding environments on roads. A particularly large number of participants in Leeds pointed out this kind of demand. This is quite understandable, as Leeds is not a good city for cycling both in terms of cycling infrastructures and overall atmosphere about cycling, while building more cycling facilities was a less important matter in York.

> "Where possible, that you could **turn more places into proper cycle paths** and consideration for **cyclists' safety at busy junctions** and that sort of thing. It's difficult, isn't it? I can kind of see how lots of people would want roads to be lots of different things, you know, for all different road users, but, yeah, **I think cyclists' safety and maybe getting cyclists off those main roads where it's dangerous if there are alternatives should be a priority**." (L2)

Maintenance was another popularly mentioned demand. It seems that maintenance was in more important demand in York than Leeds when considering the overall frequencies mentioned. Maintenance included various things such as lightings, potholes and waste.

> "it obviously **hasn't been maintained properly**. They're not very good at fixing **potholes** in the cycle lane or problems with **manhole covers** and when there's lots of **snow**, they tend to just brush all the snow into the cycle lane. For example, if they're cleaning the road, they don't always clean the cycle lane or they just brush the dirt into the cycle lane. And drunken students throw **beer bottles** into the cycle lane, so there's **a lot of glass** between Headingley and the university. That's a major problem. I've got Kevlar tyres so I'm fine, but I have a friend of mine who doesn't, but she does the same cycle route and she's always getting punctures." (L21)

From the results, cyclists in Leeds feel that the council does not drive cycling policies in the right direction, or that they are at least doing it very slowly, while cyclists in York think that York has already good environments for cycling but rarely uses them or keeps the facilities in good conditions.

6.4 Discussions

Two things are discussed in this section: firstly, the role of cycling facilities in route choice and policy aspect, and secondly riverside paths, which was the key feature of cycling networks in York.

6.4.1 Role of Cycling Facilities

The route quality evaluation in Chapter 5 revealed that cyclists mainly choose their route to minimise trip distance or time. Safety was rather behind in importance in route choice. In the interviews, safety was rarely mentioned as a reason for the choices of current routes. However, the thesis found that there are strong relationships among traffic, safety and cycling facilities through the analysis of the questions about the latter two.

Routes can be chosen by cyclists themselves, but vehicle drivers cannot, so traffic is a quite unpredictable matter for cyclists. The relationship between safety and traffic looks very obvious; however, not many studies have actually proven anything about this relationship. Pooley et al. (2011b) found that concerns about dangers from vehicles are a major barrier to cycling in England. The thesis also found that there is a strong connection between them through the questionnaire survey.

Table 6.9 shows the key influencing features in road and traffic features in importance for route choice and feeling unsafe. In traffic speed, traffic volume and lane width, HGVs are the key route features which are important for route choice and also the main reason cyclists feel unsafe during riding. This similarity indicates that what cyclists believe is important for their route is closely related with what they feel unsafe from.

Table 6.9 Key Factors Influencing Importance for Route Choice and Feeling Unsafe

Rank	Features in importance	Mean score	Features in unsafe	Mean score
1	Icy surface in winter	5.57	High traffic speed	5.92
2	Traffic speed	5.49	Not enough distance from vehicles	5.77
3	Cycling facilities	5.00	HGVs or buses	5.52
4	HGVs	4.97	Riding in poor weather	5.52
5	Available lane width	4.97	Riding without proper lights in dark	5.19
6	Off-road paths	4.97	Large traffic volume	5.04
7	Traffic volumes	4.90		

The relationship between traffic speed and safety was not popularly studied, but empirical evidence confirmed that reducing traffic speed increased cycling safety (Pucher and Beuhler, 2008). The interviews found that cyclists felt uncomfortable or unsafe with high traffic speed. Moreover, the strength of feeling unsafe increased as HGVs or buses passed by, whereas traffic volume was related with the manoeuvring of a bicycle.

The following transcript well describes the differences in the feeling about traffic speed, volume and big vehicles.

> “I think traffic speed actually. Because you just feel like if there’s a **lot of traffic** here, you see outside that there’s a **queue of traffic**, it’s **not moving** anywhere, **I can cycle past them**, I don’t feel vulnerable, but **if that traffic zooming past me very quickly, particularly if there were big lorries that create a draft, then I’m very nervous.**” (Y21)

The actual problem of high traffic speed was a lack of time for judging and then reacting to them. From the cyclist point of view, slow traffic speed gave more chances to drivers to notify cyclists nearby and be more cautious so that cyclists can also have more time to decide their next movements.

On the other side, cyclists also pointed out that the actual importance is the space allowed for cyclists from vehicles. This argument is obvious in that, if there is enough room between cyclists and vehicles, there will be no problem. The transcript below describes this opinion.

> "Well, I think they're all a good idea and it sort of depends on the road, […] I think **it makes cars give you a bit more room**. You know like when there's the **white line marked on the road**, I think cars then, you know, they **don't then cross that white line** so much, whereas if **there's not a white line** they're **a little bit nearer**." (Y15)

As shown in the above transcript, cyclists thought that cycle lanes would provide extra space from vehicles. However, it might be just a psychological effect only on cyclists. The study of Parkin and Meyers (2010) found that drivers provide wider space to cyclists on roads without cycle lanes when they overtake bicycles.

Despite that, as shown in Figure 6.6, cyclists strongly believe that cycling facilities improve the safety of cycling routes. The previous studies also found that providing extra cycle lanes (Klobucar and Fricker, 2007) or separation of side-paths (Petritsch et al., 2006) increased the level of safety of cycling routes. The primary role of cycling facilities regardless of types was providing safety to cyclists.

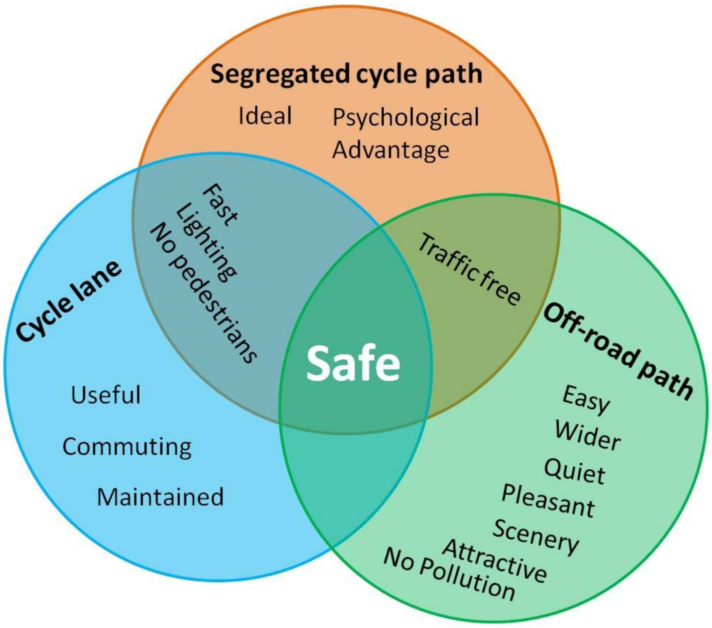


Figure 6.6 Stated Reasons of Preferences for each of Cycling Facilities

However, cyclists expected different levels of safety from each of the types. They thought that off-road paths and segregated cycle paths provide complete separation from traffic, but not from cycle lanes. Increased perceived safety with segregated cycling paths and off-road paths were also found by several studies (Parkin et al., 2007; Hopkinson and Wardman, 1996; Wardman et al., 1997). So with safety matter, off-roads or segregated paths will be the best. However, in the thesis, almost equal numbers of cyclists preferred segregated paths or cycle lanes. The previous studies were slightly skewed to preferring segregated paths more (Hopkinson and Wardman, 1996; Wardman et al., 2000; Hunt and Abraham, 2007) than cycle lanes (Stinson and Bhat, 2003; Stinson and Bhat, 2005).

The thesis also revealed why each type of cycling facilities are preferred, and the only clear difference would be a practical concern with cycle lanes and a psychological advantage of segregated cycle paths. It will be more likely just a choice of cyclists depending on preference and cyclists' confidence.

> "I think **there should be a choice**, there should be cycle lanes on the major roads so that people who want to use their bikes for commuting and they've got to get to work on time and are busy, they will **always want to use the main roads** and so they **need to do it safely**, but there **also needs to be an alternative** (segregated paths) for those **who don't have the confidence to share the road with traffic**." (Y1)

The thesis clearly showed that cyclists want cycling facilities for their safety. However, they also consider making fast trips. This will be a reason to make plans for cycling routes. However, the transcript below will provide a certain clue for this.

> "I think if there's a **cycle lane** and it's **red in colour** and **car drivers see there are cyclists**, I think they **take more care and they're a bit more cautious** and they certainly slow down and on the whole they give you a wide amount of space. I don't know, I think probably having a cycle lane that's very visible, but that is well used, is probably the safest actually because then **car drivers would change their behaviour when they see people actually using the thing and they see that it is part of their road as well**." (L11)

Cycle lanes and segregated paths will make drivers recognise that cyclists are there with them, and this will lead to changes in the behaviours of drivers in the long term. So building cycling facilities more and more will gradually increase awareness of people about the presence of cyclists and their activities as well help create a friendly atmosphere and improve the cycling network.

6.4.2 Greens and Riverside Routes

Green routes and riverside routes are basically the same type. Both routes have off-road paths and are shared with pedestrians. However, the role of the riverside routes in York is very different from the role of green routes in Leeds. Green routes in Leeds are located rather away from the central area of the city, while the riverside routes in York are located in very close to the city centre. This difference created significant different preferences between the cyclists of the two cities. Green routes in Leeds were popularly used for trips for coming back home and alternative routes, while riverside/greens routes in York were used for all kind of routes, but with significantly less frequencies for alternatives.

Both greens routes and riverside routes were welcome because of better cycling environments, such as safety (away from traffic), pleasantness and comfort. However, the key advantage with the riverside routes over greens routes was there was no difference in trip time (same in time) between using riverside routes and other possible routes or cyclists to save trip time. Cyclists can use greens routes when they are not in hurry. This makes great differences between Leeds and York in route choice.

The cases in York shows that off-road paths are more preferred if there is no disadvantage in trip time, while the cases in Leeds shows that off-road paths are less attractive if there is a disadvantage in trip time. Similar findings also appeared in the previous studies. Tilahun et al.(2007) found that off-road paths were less attractive than segregated cycle paths when they required extra time of more than 5 minutes. However, Wardman et al. (2007) also found that without considering extra trip time, off-road paths were preferred over segregated cycle paths. So, extra time is a key matter for planning off-road paths for commuting or utility cycling.

It is difficult to estimate how much extra time cyclists will permit to use longer off-road paths. The thesis found that trip time differences between main routes and alternative routes were 7.0 minutes in Leeds while they were 5.0 minutes in York. In the study of Tilahun et al.(2007), 5 minutes was accepted, while the study of TfL (2012) showed that cyclists will choose off-road paths within extra 3.17 minutes on average: 2.73 minutes for males and 5.19 minutes for females. This indicates that off-road paths should be planned not to exceed more than 5 minutes for extra trip time than its counterpart routes if they are planned for commuting and utility cycling.

On the other side, York has a geographical advantage with the location of the riverside paths. The planners can build off-road paths in a city but cannot build them like the riverside paths in York, unless there are empty areas which can be converted into off-road paths for cycling. So off-road paths in big cities which take much longer time or distance than ordinary roads will have a limited impact on cycling route choice. However, the cases in Leeds provide a little considerable issue with greens route. In the view of planning, it will be rather difficult to decide whether off-road paths are actually useful for transport cycling. However, as shown the results from the thesis, there are certain demands for greens routes as an alternative option for commuting, especially in the summer season. However, the cyclists who want greens routes did not want all sections in park areas, so planning cycling routes with mixed proportions of green area and roads will provide a better cycling environment and more choices.

6.5 Conclusions of Chapter 6

The analysis with interview revealed several key reasons for route choice, including the quickest route, greens/ riverside paths, one-way system, gradient, etc. However, the reasons had slightly different internal meanings between Leeds and York. The differences were highlighted on riverside paths in York, which was similar to greens routes overall in nature but acted differently from them in Leeds.

The analysis also found that specific facilities such as cycle lanes were not a reason for choice. Unlike the expectation, safety was rarely mentioned through the interviews. However, this does not mean these factors are not important. These elements were parts of the key reasons, especially the quickest routes and greens/ riverside paths.

Through the interviews, cyclists recognised the importance of cycling facilities and safety. Those are the ones that should be improved for better cycling environment. However, for route choices, those are just one element which influence the value of routes in the minds of cyclists; for example cyclists want cycling facilities for their safety, and a presence of cycling facilities makes the route quicker and more comfortable.

The interviews confirmed the findings in Chapter 5, such as gradual uphill and one-way systems. The interviews also found some puzzles which were not solved in chapter 5. For example cyclists in York indicated that their main routes which have a section of riverside paths were not reliable and the interviews revealed that flooding makes the routes less reliable than the alternatives to the main routes.

The findings are summarised as follows:

Key reasons to choose cycling routes

The analysis with interview data revealed that there were various reasons to use current routes for cycling. The most important four reasons were Quickest route, Greens route, One-way system and Gradient.

The quickest route was the most important reason, at least for commuting and utility cycling. The meaning of ‘Quickest’ did not simply mean shortest in time or distance; it was more complicated than we think. The quickest route was influenced by many other factors such as gradient, facility and traffic conditions.

Many cyclists used greens routes for cycling trips. However, there were two constraints in using this route. Firstly, cyclists should have enough time, as these routes were a detour rather than directly from an origin and destination. Secondly, the weather was good. Therefore this type of route was popularly used during the summer season and on the way back home.

However, there was a significant difference between Leeds and York regarding greens routes. In York there are riverside paths which are obviously a kind of green route. However, because of the advantage of the geographical location of the riverside routes, many cyclists in York used these routes for their commuting and utility cycling and enjoyed the benefits of pleasant riding and being away from traffics etc without sacrificing trip time.

One-way systems was another important reason, and many cyclists used or chose their route due to them. Notably they often force cyclists to choose a different route for coming back home from the route for going to work.

Gradient was a reason only for cyclists in Leeds. Cyclists in Leeds took routes with gradual uphill slopes rather than steep ones.

Options of cyclists to Route Features

Traffic is a rather complicated factor in cycling. High traffic speeds made cyclists felt dangerous, while a large traffic volume caused problems in manoeuvring on roads and stressed cyclists. However, stationary traffic due to large traffic volume was welcome by many cyclists. The fear of traffic can be reduced by providing enough space between cyclists and vehicles.

Cycling facilities were strongly related with safety on roads, and many cyclists believed that they improved safety. Cyclists preferred cycle lanes or segregated cycle paths for commuting and utility cycling. Off-road paths were more preferred for leisure type trips such as coming back home. However, if good off-road networks, such as riverside paths in York, are provided then off-road paths will be the best option either for safety and trip time.

Cyclists had somewhat mixed attitudes to shared bus lanes. Although shared bus lanes are not desirable, they are better than nothing. This is partially due to cyclists thinking that bus drivers are better trained and more careful than car drivers.

Junctions are also related to safety. Signalised junctions were preferred because they clearly indicates what cyclists and drivers can and cannot do, whereas, cyclists thought that drivers and cyclists were not equal at roundabouts and give-way junctions.

Advanced cycle stop lines did an important role at a signalised junction. ASL increased safety at junctions as cyclists stopped in front of cars and drivers were clearly aware of the presence of cyclists. However, cyclists complained that ASL was often encroached by vehicles, especially by taxis, and that no proper enforcement was made to prevent that.

Cyclists thought that cycling was not seriously considered by local governments, especially cyclists in Leeds. In Leeds, more cycling faculties were expected, while in York maintenance of roads or existing facilities was more expected. The differences in demands between Leeds and York reflect the different cycling environments of the cities. York has better cycling infrastructures and atmosphere for cycling, or cyclists there at least felt like that.

Chapter 7 Conclusions

7.1 Introduction

We have presented the findings from each method in the previous three chapters, although they were not fluently linked each other. This chapter presents comprehensive interpretations of the key findings drawn from the previous chapters.

Section 7.2 presents the core findings and shows how they are the same or different according to the findings of the other studies. The comprehensive interpretations also address the last objective of the thesis. Section 7.3 discusses policy implications that could be drawn from the thesis. The policy suggestions point out how to improve cycling use as well as to improve the conditions of cycling routes. The limitations of this research are presented in section 7.4 and, finally, suggestions for further studies follow in section 7.5.

7.2 Comprehensive Interpretations

7.2.1 The Quickest Routes

The thesis determined from the questionnaire the important route features that were influencing factors for route choice, while the interview revealed the reasons for using the actual routes. The reasons and route features rarely matched with each other. Unlike the expectations at the beginning of the study, the individual route factors were relatively less important factors for cyclists' choices.

Cyclists strongly chose their route for the quickest trips for most of cases. However, the quickest routes in the thesis are slightly different from the shortest time or distance because the quickest routes reflect the conditions of route features such as traffic or cycling facilities.

Several actual route-based studies concluded that cyclists did not choose the shortest route in either distance or time (Raford et al., 2007; Yeboah, 2014). However, several studies also found the trip time or distance or minimising distance to be the most important factors for route choices (Dill and Gliebe, 2008; Stinson and Bhat, 2003; Van Shagen, 1990; Westerdijk, 1990). These results indicate that although cyclists do not choose the shortest paths, they take into account the minimisation of trip time and extra factors together.

Trip distance is a rather fixed value, being that distance itself is not changeable while time is changeable according to various external factors for the same distances. Broach et al. (2011) find that travel times and distance are interchangeable, while travel times influence some non-distance variables. However, this thesis suggests that the quickest routes are influenced by non-distance variables. Thus, the quickest routes should be interpreted as the combination of minimising trip time and route feature effects.

Few studies have been conducted to study the relationship between the perceived fastest of cycling routes and the conditions of cycling route features; hence, it is not possible to compare the results of the thesis with other studies. However, the thesis found that traffic, cycling facilities and gradient are the three key factors influencing the quickest routes. Most of the studies have focused on heavy traffic where it was found that there was a negative correlation with preferences of cyclists (Broach et al., 2011; Sener et al., 2009). However, our thesis has found that, in certain cases, heavy traffic become a positive factor for route choices; for example, stationary status in peak time as well as conditions of less traffic. This condition is probably extraordinary in comparison to the usual conditions, insofar as cyclists do not like roads with lots of cars. Hence, further studies of this condition will be required.

Cycling facilities are another factor determining the quickest routes. Many studies revealed that cyclists prefer or choose a route with cycling facilities, such as cycle lanes (Tilahun et al., 2007; Sener et al., 2009). However, why do cyclists prefer a route with cycle lanes? Cyclists in Metro Vancouver, Canada chose roads with cycle lanes instead of direct routes without cycle lanes for safety (Winters et al., 2010). The thesis found that cyclists preferred cycling facilities for quick trips, as well as for comfortable and safe trips. The interviews clearly showed that cyclists think cycling facilities improve the safety of the routes. However, they also think that cycling facilities decrease trip times. Thus, these results indicate that cycling facilities serving only one purpose – to be safe or fast - will not be welcomed by cyclists.

Hilliness was a relatively unimportant factor (Menghini et al., 2010), although cyclists tend to avoid steep hills (Hood et al., 2011; Sener et al., 2009;

Stinson and Bhat, 2003). However, hilliness becomes a significant factor as gradient increases (Broach et al., 2011). Cyclists in Leeds took advantage of downhill conditions for route choices and gradual uphill routes instead of steep uphill climbs. However, in general, hilliness seems a less important factor for route choice; only when cyclists feel it extremely hard to cycle upwards does it become an important factor. Hence, cyclists have chosen the second best for their quickest routes.

7.2.2 Better Locations of Off-road Paths : An Example from York

The second important reason for the route choices was the existence of greens routes and riverside paths which are off-road paths. The motivation for choosing these routes is pleasant and comfort riding.

The study of Dill and Gliebe (2008) found that cyclists in Portland, USA chose avoiding large traffic as the most important factor for home trips or recreational trips. Whereas the study of Van Shagen (1990) found that time or distance were the most important factors for route choice in Groningen, Netherlands and distance in Växjö, Sweden, regardless of the purposes of a trip. However, the case of Groningen also showed that relatively large cyclists chose pleasantness and attraction, respectively, for the second important factor for home trips and shopping trips. Hence, these results demonstrated that cyclists chose routes by different criteria depending on trip purposes.

The thesis found that greens routes were another important reason for routes of cycling back home and alternative routes in Leeds while greens routes were chosen for personal trips in Leeds. These findings are not exactly consistent with the findings of the studies of Dill and Gliebe (2008) or Van Shagen (1990). However, at least they show that cyclists chose off-roads paths for comfort and pleasant riding for relatively less time-restricted trips. A greater number of preferences for off-road paths were found by other studies (Winters and Teschke, 2010) while the majority of studies concluded that cycle lanes or segregated cycle paths were for the most part preferred (Hopkinson and Wardman, 1996; Wardman et al., 2000; Hunt and Abraham, 2007; Stinson and Bhat, 2003). The questionnaire of this thesis also found that cycle lanes and segregated cycle paths were preferred to off-road paths in general. However, the findings reflected the general opinions of cyclists.

Cyclists prefer off-road paths, rather than main or residential roads with/without cycle lanes (TfL, 2012). The riverside paths in York showed that off-road paths are more desirable if they do not detour a lot. Many cyclists used riverside paths as the main cycling route and for a variety of trips. However, the matter is time. Cyclists in London do not want to use off-road paths when it take more than 5 minutes longer than using ordinary roads (TfL, 2012). On the other side, the extra time increased 14 minutes in the study of Tilahun et al. (2007). This thesis found that trip times on alternative routes did not exceed more than 7 minutes on average.

It would be best to provide fast and safe off-road paths to cyclists and segregated paths and cycle lanes are second options for cyclists. However, the finding from the questionnaire indicated that cycle lanes are preferred, while several prior studies conclude that segregated paths are more preferred in general. Cycling planners need to consider the weakest link in cycling activities in order to promote cycling. Less comfortable or experienced cyclists are comparatively more sensitive to the presence of cycling facilities (Stinson and Bhat, 2005; Hunt and Abraham, 2007; Sener at al., 2009). The thesis found that unconfident or beginner cyclists think that off-road paths are more important than cycling facilities. Hence, well planned off-road paths which are not very different in terms of trip time against cycle lanes or ordinary roads will be more welcome to less confident cyclists.

7.2.3 Active Cycling of Females in York and High Demand for Cycling Facilities by Females in Leeds

The thesis revealed that females cycled as actively as males in both Leeds and York. The results of actual route analysis showed that the frequencies of cycling per person per day of female cyclists were not much different from the frequencies of male cyclists, with 1.9 trips for males vs 2.1 trips for females in Leeds and 3.0 vs 2.7 in York. However, the actual cycling rates of women are far different between Leeds and York. 41.1% of the cyclists cycling to work were women in York, while only 17.7% were women in Leeds.

It is usually believed that males cycle more than females (Tilahun et al., 2007; Krizek et al., 2005; Rietveld and Daniel, 2004; Rodriguez and Joo, 2004; Moudon et al., 2005; Stinson and Bhat, 2005; Dill and Voros, 2007). However, some studies have concluded that there is no difference between cycling activities by gender (Wardman et al., 2007; Witlox and Tindemans, 2004). Moreover, it is noticeable that females cyclists are very active in the countries with high cycling rates such as the Netherlands, Denmark and Germany (Garrard et al., 2003)

Hence, the cycling rate of women seems a kind of index of cycling friendly environment of the city or nations. For the case cities of the thesis, despite there not being much different in the frequencies of cycling trips per day between men and women regardless of city, the proportion of female cyclists in Leeds is significantly lower than the proportion in York. The overall rate of cycling to work in York is 11.2%, while it is 1.8% in Leeds according to the 2011 Census (Nomis, 2014).

Safety concerns regarding traffic are the main barrier to cycling, while poor infrastructure and policies or regulations make the situation worse for women (Garrard et al., 2006; Pucher and Dijikstra, 2003). This conclusion is consistent with the findings of the thesis, which shows higher cycling rates of women and high scores in the quality evaluation for cycling facilities in York, while there are low cycling rates of women and low scores in the quality evaluation for cycling facilities in Leeds.

The contrasting cycling use of females between Leeds and York and the higher demand for cycling facilities by women in Leeds suggest that making females cycle easily is a key criteria for the success of cycling related policies. Hence, cycling facilities are one of the key measures for this trend.

7.3 Implications of Policy

The thesis has found several important points pertinent to the planning of cycling network and promoting cycling.

7.3.1 Targeting Female Cyclists

The characteristics of cyclists are not homogenous (Damant-Sirois et al., 2013; Kruger et al., 2016) and their demand for cycling routes and deterrent to cycling activities are also different (Gatersleben and Appleton, 2007). It is necessary to facilitate different strategies for different cyclist groups (Jacobsen, 2003). However, the question is who will be a right target for specific routes or infrastructures plans or increasing cycling uses.

The thesis found that the expected quality of individual route features were far higher with females. The more important point is that the cycling activities of females were more active in York than in Leeds and York has a higher cycling rate than Leeds. Is there any relationship between the cycling rate of a city and the number of female cyclists?

Although there are many exceptions, there is actually a positive relationship between them (Figure 7.1). The average percentage of cycling to work for females was 26.8% in England and Wales (Nomis, 2014). However, when the percentage of females who cycled to work for individual local authorties was compared with the overall percentage who cycled to work, most of the authorities with more than 5% of working residents cycling to work had more females cycling to work than the average percentage, except for only one authority. This result shows that females should be the key targets for increasing cycling use, even if more males cycle overall.

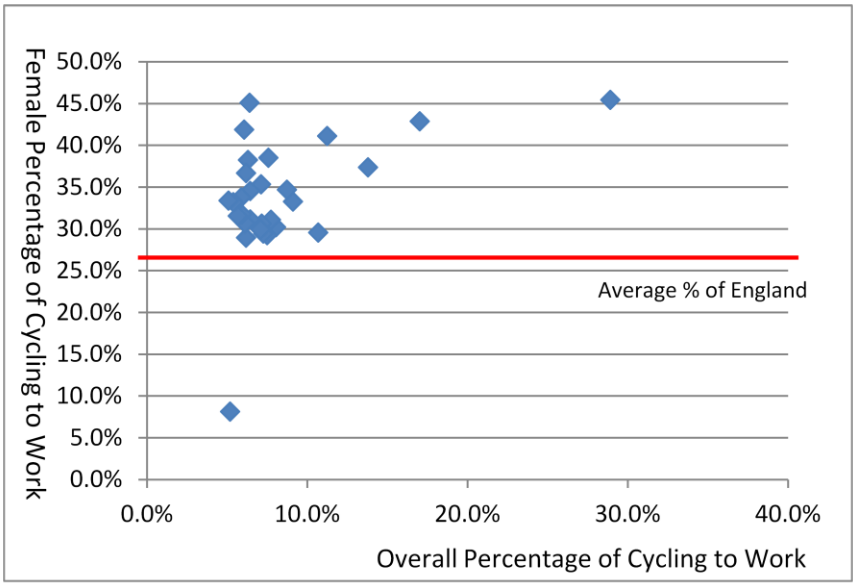


Figure 7.1 Rate of Cycling to Work Vs Female Percentage (Data source: Nomis, 2014)

In the aspects of cycling routes, this finding indicates that standards of cycling infrastructures and planning strategies for cycling network should meet the expectations of female cyclists and potential female cyclists.

Through the questionnaire, the thesis found that female cyclists were more concerned with safety from traffic, while more preferred off-road paths, wider road lanes, and cycling facilities than male cyclists. The expectations of female cyclists are important in another way, for their demands for cycling routes were similar to the demands of unconfident or beginner cyclists. They shared stronger fears about traffic and higher demands on off-road paths and cycling facilities and separation from traffic. The findings from the questionnaire were clear that cycling policies should target females because female cyclists are more cautious and conservative. However, if they feel that cycling is safe enough on roads, then they will cycle as actively as males for more various purposes, which was shown in the case of York.

7.3.2 Investing Infrastructure in Right Places

The role of cycling facilities is critical to promoting cycling for non-cyclists and also to make unconfident cyclists keep their bicycles and cycle more. Although safety was not a major factor determining route choice in the thesis, it was an important hidden factor. Safety concern is actually an important barrier (Pooley et al. 2011b; Pucher and Buehler, 2006; Southworth, 2005; Stinson and Bhat, 2004; Rietveld and Daniel, 2004; Pucher et al., 1999). This thesis found that cyclists feel much safer when there is a cycling facility along a route, even if it is just a simple painted line. Hence, reducing safety concerns is the key to promoting cycling.

However, building cycling network should meet the actual demands of cyclists. At the moment, non-cyclists will cycle along the routes that current cyclists ride in the future. The demands of potential cyclists cannot then be very different from the demands of current cyclists.

The route data showed where cyclists frequently ride. In both cities, it was in central areas where most cycling activities occurred. Cyclists do not want to leave the main road network as most activities in their life take place there. The road network was therefore planned to meet the largest demand of the citizen who live there. Hence, building the cycling network away from central areas would make no sense for cyclists.

The two case study cities show very contrasting pictures of cycling networks (see Figure 5.9). The majority of the network in Leeds is located in the south east of the city. However, the majority of the recorded trips were made in the north of the city. This mismatch may have occurred through the intended avoidance of planners or the lower hierarchy of cycling in the planning of transport network, perhaps the thoughts that cycling is still for leisure rather than transport means.

The thesis found that the characteristics of routes required by cyclists are various. There were distinctive differences between to-work trips or personal trips and back-home trips. The back-home trips require that the routes be more relaxed and comfortable and away from traffics. Thus, for those trips, the routes can be established away from main roads. However, the routes should not be too far away from the routes that the cyclists currently choose to use. Cyclists do not want to spend too much extra time on their trips because they cycle for transport from one place to another, not for recreation.

Cycling network plans should be based on the actual routes that cyclists currently use. Investing funds in places that are far away from the actual demands of cyclists is just another waste of money, leading to complaints about unrealistic plans.

7.3.3 Listen to Cyclists for Better Cycling Network

Cycling network should be designed for more convenient cycling. The interviews found that cyclists had to choose a different route from the route that they usually use due to traffic systems such as one-way systems. The problem is that the route they chose due to the one-way system was not for convenience or any advantage of the route. One-way systems force cyclists to take longer detours. However, unlike drivers in cars, taking longer detours is a negative aspect to cycling: it is harder, takes more time and often force cyclists to use main busy roads (EC, 2016) Cyclists made complaints about that system. In fact, many cyclists simply ignore the rule which is for a potentially risky behaviour for both cyclists and drivers.

Many cities in the Netherlands already allow cycling in both directions in one-way streets with traffic calming measures (Pucher and Buehler, 2008). A few local authorities in England and Ireland also take measures to allow cycling in both directions in one-way roads.(Melia, 2015; RBKC, 2016).

What is important in planning for cycling is that local authorities pay more attention to cycling and find measures which make people cycle in a more convenient environment. Cyclists already know what needs to be improved in their cycling environment. Thus, someone who is in charge needs to listen to the voices from cyclists and reflect on the planning. If there are no disadvantages to using cars or advantages to cycling, then no-one would consider cycling as a transport means.

7.4 Research Limitations

This thesis has provided valuable findings to understand cyclists' route choices. The thesis compared different preferences and choices by different characteristics of cyclists. However, the thesis has its limitations and they are highlighted below:

7.4.1 Limitation of the Research Design

The thesis adopted explanatory design in which quantitative methods and qualitative methods were conducted in order. The design is good as it explains the results of quantitative methods with qualitative methods. However, the findings from the interviews are rather unexpected and different from the results of the questionnaire. As a result, the research design of the thesis had limitations to explain the results of the questionnaire analysis in terms of the results of the interviews.

The thesis found that many unexpected reasons for route choices from interviews such as one-way system or riverside paths. However, there was no further chance to explore more about the newly revealed findings from the interviews. The reason to conduct interviews was to investigate details about the themes. However, our research only found a certain set of reasons and did not investigate the unexpected reasons in more details. Hence, the design of our study did not fully utilise the advantages of qualitative methods.

Suggestions for improved research designs can be set out in the following ways. The first suggestion is to add another interview phase to explore together the findings from an analysis of actual routes and interviews. The second interview phase would focus only on key reasons and more narrowed topics which were not identified in the previous studies, such as one-way system, differences between riverside paths and greens routes, influences of cycling facilities in safety etc. However, this approach would still have weaknesses in explaining results of the questionnaire with results of the interview. Furthermore, the study will require much time for data collection and analysis.

The second approach will be to remove the questionnaire part, then add a reformed questionnaire after the interviews. The reformed questionnaire only makes questions relevant to the findings from the interviews and actual routes. This approach can narrow down the research scope only to the topics derived from collected routes and interviews and can focus only on new findings and their explanations. However, this approach will lose the opportunity to explore the influences of preference towards various route features by the characteristics of cyclists such as confidence level, gender etc.

7.4.2 Limitation of the Research

The thesis includes only 5 working days of cycling activities. The reason why only week days were surveyed was that we simply assumed that not much utility cycling could take place during weekends. Moreover, we wanted to shorten survey periods due to not having enough numbers of GPS devices. However, many utility activities occurred during weekends as well as weekdays in York, whereas relatively non-commuting cycling was rare in weekdays in Leeds. However, during the interviews, cyclists in Leeds mentioned that they participated in non-commuting cycling in weekends. Hence, it may prove a lost chance to examine utility cycling activities during weekends and to compare them

The route data recorded was not fully interrogated. The study interviews concerned selected routes due to limited time and the interviews mainly focused on commuting trips and their routes. Meanwhile, the other trips and routes that were not selected will also have their own reasons for being chosen in terms of good and bad features.

The study showed very limited characteristics of the recorded routes. Furthermore, the GPS data analysis provided fairly simple descriptive results showing trip distance, time and speed. However, a few studies already showed that using the actual route data could provide more detailed characteristics of the chosen routes, such as proportions of road classes or the number of traffic lights, or carried out further analysis using GIS (Aultman-Hall et al., 1997; Dill and Gliebe, 2008; Howard and Burns, 2001; Menghini et al., 2010, Pooley et al., 2011b). However, conducting further analysis and showing more detailed features of routes requires much more time and effort, and could so constitute another possible project in future studies of cycling routes.

7.5 Further Research Suggestions

Some further research may be carried out expanding on the findings from the study and by personal interests. This study has not fully contributed to understanding the route choice behaviour of early stage cyclists, who have cycled relatively short periods or are fairly new to commuting by bicycle. Understanding the behaviour of new cyclists is to recognise that their experience is rather more important than any others in terms of desirable cycling environment. Without precise segmentation of cyclists' experience levels on road and enough samples for such study, what cyclists say would still be too broad and not relevant to new cyclists. However, it is also true that recruiting such new cyclists is not easy, practical and may cost a lot.

It would be interesting to use different devices to record actual data. Nowadays, smartphones are becoming common and GPS chips in smartphones are often better or equal in the accuracy of their positioning. Furthermore, with a little training in uploading data online, using smartphones allows a longer period of recording and a greater set of data. In addition, specifically developed application can be installed into smartphones and used for research; for example, participants can record the reasons for trips, where they begin and their destination type etc. Moreover, connecting GIS with such a massive quantity of route data improves the quality of analysis.

Several studies have already used GIS for analysis and compared GIS-generated thematic routes with actual routes (Aultman-Hall et al., 1997; Dill and Gliebe, 2008; Howard and Burns, 2001). These prior studies have showed differences between the generated routes and actual routes in distance, time, perceived safety levels or a number of traffic lights etc. A similar analysis with GIS for detailed route features - for example, the number of lanes, lane width, traffic volume and traffic speed - will provide a better understanding of cyclists' route choice behaviour.

The thesis examined only two proximate cities. However, expanding the study to other countries will be interesting, while the quality of cycling route or the road environment for cycling will be different in each country. Thus, measuring the perceived quality of cycling routes from cyclists' point of view and the actual quality of cycling route may be needed to develop certain standards. Meanwhile, comparing the findings will be interesting because they will show gaps between perceived values and the actual values of the cycling environment and infrastructure, as well as the expected standards for cycling routes for each country and internationally.

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Appendix 1: Questionnaire Survey Form

Cycling Questionnaire

Institute for Transport Studies
Faculty of Environment

UNIVERSITY OF LEEDS

We are carrying out research on cyclists' route choice behaviours. As a part of the research, we would like to know your preference on various aspects of cycling routes, for example traffic levels, safety, existence of cycling facilities etc as well as your cycling experience and basic demographic information.

This survey is intended for cyclists who are over 17 years old and cycling in Leeds or York. And it is not intended for those who cycle for leisure or touring.

Your responses will be kept strictly confidential within the research team, and you will not be identified or identifiable in the report or reports that result from the research.

The anonymised data collected from this questionnaire will be securely stored, and may be used in future research related to cycling and managed by only the research team.

Please return the completed questionnaire by ________

If you have any further enquiry about this questionnaire or the research, please contact me at the address below:

Name of Researcher: Doh Kyoum Shin

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Section 1. Personal cycling Information

1. What type of cyclist are you? (Tick all that apply)

[ ] Commuter cyclist
[ ] Utility cyclist (e.g. shopping, visiting friends)
[ ] Leisure cyclist
[ ] Touring cyclist
[ ] Occasional cyclist
[ ] All weather cyclist
[ ] Fair weather cyclist
[ ] Other (please specify) ______________________________

2. How long have you been cycling?

[ ] Under 3 months
[ ] 3 months to 6 months
[ ] 6 months to one year
[ ] One year to three years
[ ] Over three years

3. With reference to your answer in Q2,
Have you had periods of more than three months when you have not ridden a bicycle in the last three years?

[ ] None
[ ] Rarely
[ ] Sometimes
[ ] Often

4. How often did you cycle in the last month excluding cycling for leisure or touring purposes?

[ ] 5+times per week
[ ] 3~4 times per week
[ ] 1~2 times per week
[ ] 1~3 times per month
[ ] less than 1~3 times per month

5. How do you best describe your cycling experience?

[ ] New to cycling
[ ] Inexperienced
[ ] Starting to cycle again but inexperienced
[ ] Starting to cycle again but experienced
[ ] Somewhat experienced
[ ] Fairly experienced
[ ] Very experienced
[ ] Other (please specify) ______________________________

Section 1. Personal cycling Information - Continued

6. How do you feel about the following situations when you cycle on roads in general?

(1:Very unconfident 7: Very confident)

	1	2	3	4	5	6	7	Don't Know
a. When there are a lot of vehicles								
b. When there are few vehicles								
c. When vehicles are travelling at high speeds								
d. When vehicles are travelling slowly								
e. When Heavy goods vehicles or buses are passing by me								
f. When changing a lane in traffic								
g. When making a right turn with vehicles at junctions								

7. How important are the following reasons in keeping you cycling?

(1: Very unimportant 7:Very important)

	1	2	3	4	5	6	7	Don't Know
a. Health/Fitness								
b. Speed compared to other transport modes								
c. Reliability/Avoiding traffic congestion								
d. Environmental concerns								
e. Saving transport costs								
f. Encouragement from friends or family members								
g. No public transport or car available								
h. Promotion by employer or government (example: Cycle-to-work scheme)								
i. Other (please specify) ______________________								

8. What is your main transport for daily journeys? (Tick one only)

[ ] Train
[ ] Taxi
[ ] Bus or minibus
[ ] Car as driver
[ ] Car as passenger
[ ] Motorcycle or scooter
[ ] Walk
[ ] Bicycle
[ ] Other (please specify) ____

9. Have you been involved in a dangerous situation when riding a bicycle?

[ ] No
[ ] A near miss
[ ] Slight accident, but no medical treatment
[ ] Slight accident with medical treatment
[ ] Serious accident

The questions in Section 2 to Section 5 relate to your preferences for cycling routes in general. Please answer based on your experiences of commuting or utility trips which you make most frequently.

Section 2. Preference on Cycling Facilities

The questions in this section ask you about your experiences of having used various cycling facilities which may be available along cycling routes, your preferred facilities, and why and how much you value these facilities.

10. Which cycling facilities have you used before or do you use currently? (Tick all that apply)

[ ] Cycle lanes
[ ] Segregated cycle paths on the road
[ ] Shared paths with pedestrians
[ ] On-road cycle lanes (sharing with vehicles)
[ ] Shared lanes with buses
[ ] Off-road cycle paths such as paths in park
[ ] A bridge with a facility only for cycling
[ ] Advanced cycle stop lines
[ ] Cycle crossing facilities (e.g. Toucan crossing)
[ ] Other (please specify) ________________

11. How much would you be interested in the following facilities if you could use them for your trips?

(1: Not interested at all 7:Very interested)

	1	2	3	4	5	6	7	Don't Know
a. Cycle lanes								
b. Segregated cycle paths on the road								
c. Shared paths with pedestrians								
d. On-road cycle lanes (sharing with vehicles)								
e. Shared lanes with buses								
f. Off-road cycle paths such as paths in park								
g. A bridge with a facility only for cycling								
h. Advanced cycle stop lines								
i. Cycle crossing facilities (e.g. Toucan crossing)								
j. Other (please specify) ________________								

Section 2. Preference on Cycling Facilities - Continued

12. Of the cycling facilities in Q11, how important do you think they are for the followings...?

(1: Very unimportant 7: Very important)

	1	2	3	4	5	6	7	Don't Know
a. Safety of cycling route								
b. Saving journey times								
c. Comfortable/pleasant riding								
d. Minimising journey distance								
e. Reliable journey (e.g. being sure to get there on time)								
f. Other criteria (please specify)____________								

13. How much do you agree with the following statements with respect to your cycling route choice in general?

(1: Strongly disagree 7: Strongly agree)

	1	2	3	4	5	6	7	Don't Know
a. The continuous provision of cycling facilities is more important than the provision of cycling facilities at certain sections of a route.								
b. I prefer a route near to a cycle parking facility								

Section 3. Preference on Road and Traffic Conditions

In Section 3, various road and traffic circumstances are presented which might influence your route choice for cycling. The questions will ask you about your preferences towards the various circumstances, and the importance of the various circumstances.

14. How likely are you to choose to cycle on routes with the following circumstances?

(1: Very unlikely, 7: Very likely)

	1	2	3	4	5	6	7	Don't Know
a. Large traffic volumes								
b. High traffic speeds								
c. Bus lane or frequent bus service								
d. Frequent heavy goods vehicles uses								
e. Narrow space on a lane available for cycling								
f. Wide space on a lane available for cycling								
g. Off-road paths								
h. Vehicles parked on streets								
i. Steep uphill gradient								
j. Steep downhill gradient								
k. Moderate uphill gradient								
l. Moderate downhill gradient								
m. Cycling facilities provided (e.g. facilities in Section 2)								
n. Good surface quality of pavement								
o. Poor surface quality of pavement								
p. Icy surfaces in winter								
q. Good scenery along the route								
r. Poor street lighting when it is dark								
s. Where personal or area security is not secured								
t. Traffic calming								
u. Other(please specify)__________________								

Section 4. Preference on Road and Traffic Conditions - Continued

15. How important are the following road and traffic circumstances with regard to your decision of whether or not you would use a certain route for cycling?

(1: Very unimportant 7: Very important)

	1	2	3	4	5	6	7	Don't Know
a. Traffic volumes								
b. Traffic speeds								
c. Available lane width for cycling								
d. Buses and bus lane								
e. Heavy goods vehicles								
f. Off-road path								
g. Vehicles parked on streets								
h. Gradient								
i. Cycling facilities provided								
j. Surface quality of pavement								
k. Icy surfaces in winter								
l. Scenery along the route								
m. Poor street lighting/ Darkness								
n. Personal or area security along a route								
o. Traffic calming								
p. Other feature (please specify)______________								

16. With regard to your answers to Q14 and Q15,
How important are the following reasons in your decision in the previously mentioned circumstances?

(1: Very unimportant 7: Very important)

	1	2	3	4	5	6	7	Don't Know
a. Safety of cycling route								
b. Saving journey times								
c. Comfortable/pleasant riding								
d. Minimising journey distance								
e. Reliable journey (e.g. being sure to get there on time)								
f. Other (please specify)__________________								

Section 4. Preference on Intersections on Route

Section 4 asks you about your behaviour at an intersection and what influences your use of intersections.

17. How well do these statements describe your cycling behaviour?

(1: Strongly disagree 7: Strongly agree)

	1	2	3	4	5	6	7	Don't Know
a. I tend to avoid junctions with traffic lights								
b. I tend to avoid junctions where you have to give way								
c. I tend to avoid roundabouts								
d. I tend to avoid intersections used frequently by vehicles								
e. I tend to avoid an intersection at which I need to make a right turn								

18. How important are the following factors in deciding whether or not you will use a certain intersection for cycling?

(1: Very unimportant 7: Very important)

	1	2	3	4	5	6	7	Don't Know
a. Size of intersection								
b. Complexity of intersection								
c. Advanced stop line provided for cycling								
d. A number of vehicles making a turn at an intersection								
e. Other (please specify)___________________								

19. How important are the following reasons in your decision to use an intersection based on your answers to Q17 and Q18?

(1: Very unimportant 7: Very important)

	1	2	3	4	5	6	7	Don't Know
a. Safety of cycling route								
b. Saving journey times								
c. Comfortable/pleasant riding								
d. Minimising journey distance								
e. Reliable journey (e.g. being sure to get there on time)								
f. Other (please specify)___________________								

Section 5. Cycling Route Safety

Various circumstances along cycling routes are likely to influence your feeling or judgement of whether a route is safe or not.
Section 5 asks you about safety along cycling routes.

20. How much do the following circumstances make you feel <u>unsafe</u> when you are cycling?

(1: Very safe, 7: Very unsafe)

	1	2	3	4	5	6	7	Don't Know
a. Large traffic volumes								
b. High traffic speeds								
c. Vehicles parked on street								
d. Steep uphill gradient								
e. Steep downhill gradient								
f. Moderate uphill gradient								
g. Not enough distance from vehicles								
h. Poor surface quality of pavement								
i. Heavy goods vehicles or buses								
j. Making a right turn at junctions								
k. Going forward at junctions								
l. Changing a lane in traffic								
m. Pedestrians appearing suddenly								
n. Riding on roads in poor weathers (e.g. icy surfaces, heavy rain or strong wind)								
o. Riding along the route without proper lights when it is dark								
p. Surrounding environment of areas nearby a route								
q. Others (please specify)____________________								

21. Please rank the following intersections in order of preference with respect to safety whilst cycling. (1: the safest, 3: the least safe)

	Rank
a. Junctions where you have to give way	
b. Junctions with traffic lights	
c. Roundabouts	

Section 6. Information on the cycle trip made most frequently

The questions in Section 6 relate to your cycling route. Please answer the questions based on your opinions and experiences on <u>the cycle trip which you make most frequently.(Please, exclude touring or leisure cycling trips)</u>

22. What is your trip purpose on the cycle trip you make most of the time?(Tick one only)

[ ] Going to work
[ ] Going to school/university
[ ] Shopping
[ ] Personal business (e.g. visiting friends)
[ ] Coming back home
[ ] Other (please specify) ______________________________

23. How frequently do you make this trip on average?
(Please count your number of trips either per week or per month)
(Example: Cycling to work and cycling back home count for 2 trips, whereas cycling to work and returning on public transport count for 1 trip.)

........................Number of trips/ week
Or ....Number of trips/ month

24. Which of the following best describes your reasons for choosing the route for your most frequent trip?
(Please rank the <u>three top criteria in order of</u> 1 for the first and 3 for the third)

[ ] to minimise trip time
[ ] to minimise trip distance
[ ] to have the safest route
[ ] to have the most reliable route (e.g. being sure to get there on time)
[ ] to have the most pleasant route
[ ] to have the flattest route
[ ] to have the least complicated route
[ ] to use cycling facilities such as cycle lane
[ ] other criteria (please specify) ______________________________

25. Do you think your chosen route is safe for cycling?

[ ] Yes, It's very safe
[ ] Yes, it's fairly safe
[ ] I am not sure
[ ] No, it's unsafe
[ ] No, it's extremely unsafe

Section 7. Demographic Details

26. Where do you usually live?
(Please provide the first half of your post code or the area name)
[ ] Leeds
[ ] York
____

27. What is your age?
[ ] 18-24
[ ] 25-34
[ ] 35-44
[ ] 45-54
[ ] 54-64
[ ] Over 65

28. What is your sex?
[ ] Male
[ ] Female

29. What is your occupation?
[ ] Working as an employee
[ ] Self-employed with employees
[ ] Self-employed without employees or Freelance
[ ] Retired
[ ] Looking after home or family
[ ] Unemployment
[ ] Student
[ ] Other (please specify) ____

30. What is your ethnic group?
[ ] White British
[ ] White Others
[ ] Black British
[ ] Black Others
[ ] Asian British
[ ] Asian others
[ ] Other (please specify)________________________

31. What is your final education level?
(If your education level is not listed, tick the nearest equivalent)
[ ] GCSEs/O'level/CSE or less
[ ] A-level/BTEC national
[ ] Degree(BA, BSc etc)/Higher Degree (MA, PhD etc)

Section 7. Demographic Details - Continued

32. Do you have a driving licence?
[ ] Yes
[ ] No

33. How many cars do you personally own or have access to?
[ ] None
[ ] One
[ ] Two
[ ] Three
[ ] Four and more

34. There will be a follow-up study to this one at sometime in the future. Can I ask whether it would be alright to contact you again?
[ ] Yes
[ ] No

35. If you are happy to be contacted in the future, Please provide your name and contact details.
(Your personal information provided will be kept securely and used only to contact participants for further research and you will be free to withdraw at any point without giving reasons.)

Name: ________________________
Postal Address: ____
____
_____________________________Post code______________
Phone: ______________________________
Email: ______________________________

Thank you for your participation to this survey.

Have a nice day.

Appendix 2: Route Evaluation Form

Interviewee Name	
GPS device No.	

Route Evaluation Sheet

The interview sections 1 and2 are recorded by an interviewer

An interviewee is required to fill in section 3

Section 1. Checking recorded routes			
Q1	Was there any problem with the GPS device or the survey? If so, please report them here		
Q2	Total number of routes recorded		
Q3	Did you make any trips not recorded with the device?		
	☐ Yes (go to Q4)	☐ No (go to Section 2)	☐ Don't know (go to Section 2)
Q4	If yes, how many trips are not recorded?		
Q5	What were the reasons the trips were not recorded? (tick all those which apply)		
	☐ I forgot to take the device		
	☐ I didn't want to take the device		
	☐ I forgot to turn on		
	☐ I had the device and turned on, but the trips were not recorded		
	☐ The batteries were dead		
	☐ Other(please specify)		

If there is any alternative route suggested in the previous section, ask a participant to use the route in Section 4 as an alternative route.

Otherwise, ask a participant to use routes generated by GIS as an alternative route.

Section 2. Route details					
1.	Route No.		2.	Trip frequency	
3.	Origin		4.	Destination	
5.	Trip purpose				
6.	Track point accuracy		7.	Fault recording amended	

Section 3. Route Evaluation Form									
Please rate the quality for the following criteria for your route (1: Very bad, 7: Very good)									
Items	Route								
	1	2	3	4	5	6	7	Not applicable	
Minimising journey distance									
Minimising journey time									
Having the safe route									
Having the reliable route									
Having the pleasant/comfortable route									
Any other									

Section 3. Route Evaluation Form									
Please rate the quality for the following features of your route. (1: Very bad, 7: Very good)									
Items	Route								
	1	2	3	4	5	6	7	Not applicable	
Traffic volumes									
Traffic speed									
Lane width available cycling									
Buses									
HGVs									
Cycling facilities									
Vehicles parked on street									
Main roads									
Residential roads									
Roundabouts									
Signalised junctions									
Give-way junctions									
Making rights turns									
Making left turns									
Uphill gradient									
Downhill gradient									
Surface quality									
Good scenery									
Bicycle parking									
pedestrian-oriented areas									
Personal security									
Lightings (in darkness)									

Appendix 3: Interview Consent Form

Participant Consent Form

Title of Research Project: Explanation of factors influencing cyclists' route choice using actual data

Name of Researcher: Doh Kyoum Shin

Initial the box if you agree with the statement to the left

1	I confirm that I have read and understand the information sheet explaining the above research project and I have had the opportunity to ask questions about the project.	☐
2	I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline.	☐
3	I understand that my responses will be kept confidential. I give permission for members of the research team to have access to my responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research.	☐
4	I agree for audio recording and the data collected from me to be used in future research.	☐
5	I agree to take part in the above research project and will inform the principal investigator should my contact details change.	☐
6	I understand that the suggested routes as alternatives are generated by a programme and their actual criteria will be different from suggested criteria in the interview.	☐
7	I understand that any information discussed or provided during the interview is not advice, and I should use my own judgment if I try a new route, and not do anything I am not comfortable with.	☐

________________________	________________	____________________
Name of participant	Date	Signature
________________________	________________	____________________
Researcher	Date	Signature

To be signed and dated in presence of the participant

Appendix 4 Results of Statistical Analysis

4-1 Mann-Whitney U tests by Gender

Importance of Road and Traffic Features	Male	Female	Statistics		
Traffic volume	4.73	5.17	U=27,209.0	z=2.798	p=.005
Traffic speed	5.36	5.70	U=26,827.5	z=2.730	p=.006
Buses	4.25	4.46	U=25,190.5	z=1.272	p=.204
HGVs	4.85	5.16	U=26,589.0	z=2.097	p=.036
Vehicles parked on streets	3.59	3.67	U=24,419.5	z=0.541	p=.588
Lane width	4.82	5.20	U=26,011.0	z=2.059	p=.040
Gradient	3.63	4.09	U=26,554.0	z=2.399	p=.016
Surface quality	4.18	4.47	U=25,084.0	z=1.734	p=.083
Poor street lighting/Darkness	3.77	4.68	U=30,750.5	z=5.451	p=.000
Traffic calming (20 mile zone)	3.88	4.35	U=26,763.0	z=2.778	p=.005
Off-road path	4.68	5.41	U=28,716.0	z=4.043	p=.000
Cycling facility	4.89	5.17	U=24,789.0	z=1.360	p=.174
Icy surface in winter	5.43	5.79	U=26,787.5	z=2.648	p=.008
Scenery	4.35	4.05	U=21,085.0	z=-1.714	p=.086
Personal or area security	4.35	5.07	U=27,708.0	z=4.480	p=.000

Likelihood to choose	Male	Female	Statistics		
Road and traffic circumstance					
Large traffic volume	4.08	3.76	U=21,218.5	z=-1.742	p=.082
High traffic speed	3.31	2.88	U=19,949.5	z=-2.822	p=.005
Frequently running buses	4.87	4.41	U=19,362.0	z=-2.895	p=.004
Frequently running HGVs	3.61	3.22	U=19,623.0	z=-2.484	p=.013
Vehicles parked on streets	4.79	5.02	U=25,154.5	z=1.687	p=.092
Narrow space on lane	4.70	4.66	U=22,790.5	z=-0.305	p=.761
Wide space on lane	6.19	6.30	U=24,944.5	z=2.013	p=.044
Steep uphill	5.02	4.39	U=18,263.5	z=-3.978	p=.000
Steep downhill	5.50	5.09	U=19,670.5	z=-2.917	p=.004
Moderate uphill	5.65	5.57	U=22,997.5	z=-0.458	p=.647
Moderate downhill	5.95	5.81	U=22,073.5	z=-0.928	p=.353
Good surface	5.76	5.90	U=24,152.5	z=1.808	p=.071
Poor surface	4.04	3.49	U=18,034.5	z=-3.295	p=.001
Icy surface in winter	2.86	2.34	U=18,517.5	z=-3.726	p=.000
Good scenery	5.38	5.27	U=22,473.5	z=-0.356	p=.722
Poor street lighting in dark	4.33	3.44	U=16,775.5	z=-5.279	p=.000
Poor personal or area security	3.84	2.89	U=14,275.0	z=-5.717	p=.000
Traffic calming (20 mile zone)	5.26	5.51	U=24,591.5	z=1.847	p=.065

Cycling facility	Male	Female	Statistics		
Preference					
Cycle lane	6.12	6.49	U=27,828.0	z=3.672	p=.000
Segregated cycle path	6.04	6.31	U=26,115.5	z=2.208	p=.027
Shared pedestrian path	4.43	5.05	U=28,419.5	z=3.554	p=.000
On-road cycle lane	5.28	5.15	U=22,362.5	z=-0.502	p=.616
Shared bus lane	4.79	4.19	U=18,711.0	z=-3.198	p=.001
Off-road path	5.81	6.11	U=26.188.5	z=2.248	p=.025
Bridge with a facility only for cycling	5.58	5.73	U=23,374.5	z=0.808	p=.419
Advanced stop line	5.78	5.85	U=21,734.0	z=0.767	p=.443
Cycle crossing facility	5.10	5.83	U=25,669.5	z=4.119	p=.000
Agreement					
Continuity of cycling facility	5.23	5.59	U=21,986.0	z=2.069	p=.039
Prefer route near to bicycle parking	4.32	4.52	U=22,744.5	z=1.024	p=.306
Junctions					
Behaviour					
Avoid signalised junction	2.40	2.26	U=22,210.0	z=-1.078	p=.281
Avoid give-way junction	2.38	2.46	U=23,805.5	z=0.286	p=.775
Avoid roundabout	3.15	3.60	U=26,045.5	z=2.118	p=.034
Avoid junction frequently used by vehicles	2.92	3.18	U=25,015.0	z=1.319	p=.187
Avoid junction for right turn	2.90	3.18	U=25,282.5	z=1.347	p=.178
Importance of feature					
Size	4.09	4.40	U=25,604.5	z=1.919	p=.055
Complexity	4.51	4.97	U=26,932.0	z=2.842	p=.004
Advanced stop line	4.13	4.47	U=25,234.0	z=1.996	p=.046
Number of vehicles making turn	4.09	4.42	U=25,329.0	z=1.882	p=.060

Feeling unsafe	Male	Female	Statistics		
Large traffic volume	4.83	5.37	U=29,430.5	z=4.517	p=.000
High traffic speed	5.77	6.15	U=28,638.0	z=3.905	p=.000
HGVs or buses	5.33	5.81	U=29,648.0	z=4.634	p=.000
Not enough distance from vehicles	5.70	5.89	U=25,874.5	z=1.735	p=.083
Vehicles parked on street	4.15	4.23	U=24,718.5	z=0.845	p=.398
Steep uphill	2.69	3.15	U=26,784.5	z=3.129	p=.002
Steep downhill	2.88	3.53	U=28,319.0	z=4.166	p=.000
Moderate uphill	2.40	2.72	U=25,669.0	z=2.126	p=.033
Poor surface	4.44	4.67	U=22,237.5	z=1.282	p=.200
Making right turn at junction	4.08	4.51	U=26,745.0	z=2.976	p=.003
Going forward at junction	3.07	3.53	U=27,005.0	z=3.015	p=.003
Changing lane in traffic	4.23	4.74	U=28,048.0	z=3.601	p=.000
Pedestrians appearing suddenly	4.79	5.05	U=25,681.0	z=1.845	p=.065
Riding on roads in poor weather	5.30	5.87	U=30,191.0	z=5.370	p=.000
Riding without proper lights in dark	4.92	5.61	U=27,809.5	z=4.803	p=.000
Environment of areas nearby route	3.94	4.47	U=23,337.5	z=3.758	p=.000

4-2 Mann-Whitney U tests by City

Importance of Road and Traffic Features	Leeds	York	Statistics		
Traffic volume	4.87	4.94	U=25,339.5	z=0.618	p=.537
Traffic speed	5.36	5.65	U=27,451.0	z=2.446	p=.014
Buses	4.44	4.20	U=22,616.5	z=-1.363	p=.173
HGVs	4.93	5.02	U=25,844.0	z=0.825	p=.409
Vehicles parked on streets	3.79	3.43	U=21,566.5	z=-2.311	p=.021
Lane width	5.02	4.91	U=23,786.5	z=-0.390	p=.696
Gradient	3.76	3.87	U=25,284.5	z=0.685	p=.493
Surface quality	4.17	4.45	U=26,158.0	z=1.848	p=.065
Poor street lighting/Darkness	4.11	4.15	U=24,908.0	z=0.290	p=.772
Traffic calming (20 mile zone)	3.92	4.25	U=26,566.5	z=1.960	p=.050
Off-road path	4.71	5.28	U=28,491.5	z=3.175	p=.001
Cycling facility	4.93	5.09	U=24,931.0	z=0.794	p=.427
Icy surface in winter	5.42	5.76	U=27,097.0	z=2.180	p=.029
Scenery	4.27	4.19	U=23,648.5	z=-0.459	p=.646
Personal or area security	4.63	4.65	U=23,357.0	z=0.215	p=.830

Likelihood to choose	Leeds	York	Statistics		
Road and traffic circumstance					
Large traffic volume	4.07	3.82	U=22,508.0	z=-1.454	p=.146
High traffic speed	3.36	2.89	U=20,660.0	z=-2.925	p=.003
Frequently running buses	4.95	4.38	U=18,761.0	z=-3.982	p=.000
Frequently running HGVs	3.60	3.30	U=21,448.5	z=-1.810	p=.070
Vehicles parked on streets	4.64	5.17	U=28,968.5	z=3.895	p=.000
Narrow space on lane	4.70	4.67	U=23,994.0	z=-0.065	p=.948
Wide space on lane	6.15	6.34	U=26,307.5	z=2.337	p=.019
Steep uphill	4.85	4.66	U=22,711.0	z=-1.100	p=.271
Steep downhill	5.36	5.30	U=23,633.5	z=-0.401	p=.688
Moderate uphill	5.58	5.66	U=24,956.5	z=0.411	p=.681
Moderate downhill	5.90	5.89	U=23,722.0	z=-0.298	p=.766
Good surface	5.58	6.10	U=27,117.0	z=3.457	p=.001
Poor surface	3.82	3.82	U=23,220.0	z=0.150	p=.881
Icy surface in winter	2.66	2.65	U=24,152.0	z=-0.037	p=.971
Good scenery	5.29	5.39	U=24,100.5	z=0.300	p=.764
Poor street lighting in dark	3.95	4.01	U=25,039.0	z=0.389	p=.697
Poor personal or area security	3.39	3.56	U=23,492.5	z=1.118	p=.263
Traffic calming (20 mile zone)	5.22	5.53	U=26,343.5	z=2.454	p=.014

Cycling facility	Leeds	York	Statistics		
Preference					
Cycle lane	6.24	6.30	U=25,773.5	z=1.079	p=.280
Segregated cycle path	6.10	6.21	U=24,830.0	z=0.381	p=.703
Shared pedestrian path	4.46	4.93	U=28,031.0	z=2.537	p=.011
On-road cycle lane	5.31	5.12	U=22,003.5	z=-1.541	p=.123
Shared bus lane	4.88	4.17	U=18,311.5	z=-4.163	p=.000
Off-road path	5.78	6.11	U=27,043.0	z=2.177	p=.029
Bridge with a facility only for cycling	5.56	5.74	U=24,418.5	z=0.924	p=.355
Advanced stop line	5.76	5.86	U=22,964.5	Z=1.120	p=.263
Cycle crossing facility	5.18	5.65	U=24,835.0	z=2.663	p=.008
Agreement					
Continuity of cycling facility	5.25	5.51	U=22,175.5	z=1.484	p=.138
Prefer route near to bicycle parking	4.06	4.80	U=27,799.5	z=4.354	p=.000
Junctions					
Behaviour					
Avoid signalised junction	2.36	2.32	U=23,796.0	z=-0.561	p=.575
Avoid give-way junction	2.42	2.40	U=23,637.5	z=-0.588	p=.557
Avoid roundabout	3.50	3.12	U=21,579.0	z=-2.061	p=.039
Avoid junction frequently used by vehicles	3.12	2.91	U=22,421.5	z=-1.355	p=.175
Avoid junction for right turn	3.12	2.87	U=22,399.0	z=-1.533	p=.125
Importance of feature					
Size	4.34	4.05	U=21,807.0	z=-1.713	p=.087
Complexity	4.83	4.53	U=21,814.0	z=-1.815	p=.070
Advanced stop line	4.19	4.35	U=24,931.0	z=1.012	p=.312
Number of vehicles making turn	4.16	4.29	U=24,776.5	z=0.765	p=.444

Feeling unsafe	Leeds	York	Statistics		
Large traffic volume	4.98	5.12	U=26,017.0	z=1.142	p=.254
High traffic speed	5.89	5.95	U=25,763.5	z=0.871	p=.384
HGVs or buses	5.48	5.57	U=26,545.5	z=1.456	p=.145
Not enough distance from vehicles	5.76	5.79	U=24,681.5	z=0.123	p=.902
Vehicles parked on street	4.34	4.00	U=21,302.0	z=-2.442	p=.015
Steep uphill	2.81	2.95	U=25,003.5	z=0.932	p=.351
Steep downhill	3.07	3.21	U=25,214.5	z=0.931	p=.352
Moderate uphill	2.52	2.53	U=24,081.0	z=0.063	p=.950
Poor surface	4.49	4.57	U=22,243.5	z=0.403	p=.687
Making right turn at junction	4.37	4.10	U=21,194.5	z=-1.972	p=.049
Going forward at junction	3.33	3.16	U=22,615.0	z=-1.046	p=.295
Changing lane in traffic	4.55	4.29	U=22,297.0	z=-1.539	p=.124
Pedestrians appearing suddenly	4.98	4.79	U=22,449.0	z=-1.356	p=.175
Riding on roads in poor weather	5.48	5.58	U=25,856.0	z=1.182	p=.237
Riding without proper lights in dark	5.17	5.22	U=23,150.0	z=0.301	p=.763
Environment of areas nearby route	4.21	4.06	U=19,116.5	z=-0.876	p=.381

4-3 Kruskal-Wallis Multiple Comparisons by Confidence Level

Importance of Road and Traffic Features	Beginner	Unconfident	Confident	Very Confident	Statistics	
Icy surface in winter	5.72	5.71	5.51	5.44	H(3)=2.777	p=.427
Traffic speed	6.27 [3,4]	5.92 [3,4]	5.41 [1,2]	4.65 [1,2]	H(3)=51.826	p=.000
Cycling facility	5.67 [3,4]	5.39 [4]	4.89 [1]	4.32 [1,2]	H(3)=22.610	p=.000
HGVs	5.53 [3,4]	5.33 [4]	4.95 [1,4]	4.17 [1,2,3]	H(3)=31.776	p=.000
Lane width	5.76 [3,4]	5.27 [4]	4.90 [1]	4.23 [1,2]	H(3)=26.593	p=.000
Off-road path	5.69 [3,4]	5.39 [4]	4.84 [1]	4.30 [1,2]	H(3)=23.625	p=.000
Traffic volume	5.78 [3,4]	5.36 [3,4]	4.80 [1,2]	3.98 [1,2]	H(3)=49.677	p=.000
Personal or area security	5.39 [3,4]	5.02 [3,4]	4.44 [1,2]	4.08 [1,2]	H(3)=29.968	p=.000
Buses	4.77 [4]	4.54 [4]	4.39 [4]	3.70 [1,2,3]	H(3)=14.563	p=.002
Surface quality	4.42	4.30	4.25	4.22	H(3)=0.422	p=.936
Scenery	4.14	4.36	4.27	4.09	H(3)=0.789	p=.852
Poor street lighting/Darkness	5.05 [1,2,3]	4.19 [1]	3.98 [1]	3.66 [1]	H(3)=25.614	p=.000
Traffic calming(20 mile zone)	4.81 [3,4]	4.21	3.91 [1]	3.66 [1]	H(3)=18.092	p=.000
Gradient	3.86	3.87	3.88	3.52	H(3)=2.506	p=.474
Vehicles parked on streets	3.73	3.85	3.61	3.31	H(3)=4.478	p=.214

Items in superscript indicate which means are significantly different from each other (Kruskal-Wallis Multiple comparisons)

Likelihood to choose	Beginner	Unconfident	Confident	Very Confident	Statistics	
Road and traffic circumstance						
Large traffic volume	2.75^{3,4}	3.45^{3,4}	4.15^{1,2,4}	4.93^{1,2,3}	H(3)=63.896	p=.000
High traffic speed	2.28^{3,4}	2.48^{3,4}	3.28^{1,2,4}	4.21^{1,2,3}	H(3)=71.677	p=.000
Frequently running HGVs	2.62^{3,4}	2.85^{3,4}	3.63^{1,2,4}	4.40^{1,2,3}	H(3)=63.886	p=.000
Frequently running buses	3.76^{3,4}	4.41^{4}	4.89^{1}	5.29^{1,2}	H(3)=36.931	p=.000
Parked vehicles on street	4.36^{4}	4.65^{4}	4.89^{4}	5.50^{1,2,3}	H(3)=26.952	p=.000
Traffic calming	5.47	5.07^{4}	5.33	5.64^{2}	H(3)=12.290	p=.006
Poor personal or area security	2.84^{3,4}	3.01^{4}	3.54^{1,4}	4.32^{1,2,3}	H(3)=39.309	p=.000
Poor street lighting when dark	3.03^{3,4}	3.69^{4}	4.12^{1,4}	4.67^{1,2,3}	H(3)=39.849	p=.000
Icy surface in winter	2.21^{3,4}	2.29^{4}	2.75^{1}	3.20^{1,2}	H(3)=24.156	p=.000
Narrow space on lane	4.25^{4}	4.26^{4}	4.63^{4}	5.53^{1,2,3}	H(3)=38.432	p=.000
Wide space on lane	6.57^{1}	6.06^{2}	6.23	6.18	H(3)=10.606	p=.014
Steep downhill	4.92^{4}	5.11^{4}	5.35^{4}	5.87^{1,2,3}	H(3)=20.386	p=.000
Moderate downhill	5.73	5.70^{4}	5.89	6.25^{2}	H(3)=12.487	p=.006
Steep uphill	4.02^{3,4}	4.58^{4}	4.76^{1,4}	5.48^{1,2,3}	H(3)=33.009	p=.000
Moderate uphill	5.25^{4}	5.47^{4}	5.56^{4}	6.12^{1,2,3}	H(3)=23.919	p=.000
Poor surface	3.65^{4}	3.29^{3,4}	3.92^{2}	4.47^{1,2}	H(3)=23.480	p=.000
Good Surface	6.08	5.56^{4}	5.74	6.06^{2}	H(3)=10.560	p=.014
Good scenery	5.49	5.17	5.32	5.45	H(3)=5.265	p=.153

Items in superscript indicate which means are significantly different from each other (Kruskal-Wallis Multiple comparisons)

Cycling facility	Beginner	Unconfident	Confident	Very Confident	Statistics	
Preference						
Cycle lane	6.59[3,4]	6.45	6.19[1]	5.96[1]	H(3)=11.004	p=.012
Segregated cycle path	6.54[3]	6.31	6.01[1]	5.96	H(3)=10.180	p=.017
Off-road path	6.52[3,4]	6.09	5.76[1]	5.66[1]	H(3)=18.261	p=.000
On-road cycle lane	4.68[3,4]	5.18	5.29[1]	5.43[1]	H(3)=13.020	p=.005
Shared bus lane	3.52[3,4]	4.34[4]	4.71[1]	5.05[1,2]	H(3)=28.739	p=.000
Cycle crossing facility	5.84[4]	5.62	5.26	5.05[1]	H(3)=10.345	p=.016
Bridges with a cycling only facility	6.30[3,4]	5.75	5.44[1]	5.51[1]	H(3)=17.218	p=.001
Advanced stop line	5.88	5.86	5.75	5.79	H(3)=0.691	p=.875
Shared pedestrian path	5.02	4.88	4.50	4.48	H(3)=5.820	p=.121
Agreement						
Continuity of cycling facility	5.85[3]	5.56	5.05[1]	5.42	H(3)=12.185	p=.007
Prefer route near to bicycle parking	4.64	4.34	4.37	4.31	H(3)=1.772	p=.621
Junctions						
Behaviour						
Avoid roundabout	4.77[3,4]	3.86[3,4]	3.05[1,2,4]	2.37[1,2,3]	H(3)=62.338	p=.000
Avoid give-way junction	3.37[3,4]	2.55[4]	2.22[1]	2.02[1,2]	H(3)=36.523	p=.000
Avoid signalised junction	3.13[3,4]	2.42[4]	2.26[1,4]	1.94[1,2,3]	H(3)=28.105	p=.000
Avoid junction frequently used by vehicles	4.47[3,4]	3.62[3,4]	2.66[1,2,4]	2.09[1,2,3]	H(3)=79.124	p=.000
Avoid junction for right turn	4.38[3,4]	3.63[3,4]	2.64[1,2,4]	2.17[1,2,3]	H(3)=68.241	p=.000
Importance of feature						
Complexity	5.41[3,4]	5.21[4]	4.75[1,4]	3.56[1,2,3]	H(3)=44.961	p=.000
Size	5.02[3,4]	4.55[4]	4.17[1,4]	3.41[1,2,3]	H(3)=31.372	p=.000
Number of vehicles making turn	5.28[3,4]	4.70[4]	4.18[1,4]	3.11[1,2,3]	H(3)=55.752	p=.000
Advanced stop line	5.03[4]	4.47[4]	4.32[4]	3.39[1,2,3]	H(3)=28.815	p=.000

Feeling unsafe	Beginner	Unconfident	Confident	Very Confident	Statistics	
High traffic speed	$6.75^{2,3,4}$	$6.32^{1,3,4}$	$5.83^{1,2,4}$	$5.08^{1,2,3}$	H(3)=87.953	p=.000
Riding on roads in poor weather	$6.14^{3,4}$	5.66^{4}	$5.52^{1,4}$	$4.98^{1,2,3}$	H(3)=27.792	p=.000
HGVs or buses	$6.38^{2,3,4}$	$5.93^{1,3,4}$	$5.46^{1,2,4}$	$4.67^{1,2,3}$	H(3)=78.908	p=.000
Riding without proper lights in dark	5.63^{4}	5.33	5.16	4.70^{1}	H(3)=12.623	p=.006
Large traffic volume	$6.23^{2,3,4}$	$5.39^{1,3,4}$	$4.88^{1,2,4}$	$4.16^{1,2,3}$	H(3)=105.546	p=.000
Changing lane in traffic	$5.56^{3,4}$	$4.99^{3,4}$	$4.30^{1,2,4}$	$3.38^{1,2,3}$	H(3)=94.162	p=.000
Making right turn at junction	$5.29^{3,4}$	$4.77^{3,4}$	$4.04^{1,2,4}$	$3.39^{1,2,3}$	H(3)=71.488	p=.000
Environment of areas nearby route	$4.87^{3,4}$	$4.57^{3,4}$	$4.05^{1,2,4}$	$3.41^{1,2,3}$	H(3)=43.837	p=.000
Not enough distance from vehicles	$6.48^{3,4}$	6.04^{4}	$5.73^{1,4}$	$5.06^{1,2,3}$	H(3)=52.581	p=.000
Pedestrians appearing suddenly	5.27^{4}	5.12^{4}	4.96^{4}	$4.27^{1,2,3}$	H(3)=21.378	p=.000
Vehicles parked on street	4.52^{4}	4.44^{4}	4.17	$3.73^{1,2}$	H(3)=13.777	p=.003
Going forward at junction	$4.16^{3,4}$	3.55^{4}	3.09^{1}	$2.71^{1,2}$	H(3)=36.618	p=.000
Steep downhill	$3.75^{3,4}$	$3.47^{3,4}$	$2.97^{1,2}$	$2.68^{1,2}$	H(3)=24.403	p=.000
Steep uphill	$3.46^{3,4}$	3.02	2.76^{1}	2.53^{1}	H(3)=14.898	p=.002
Moderate uphill	2.72	2.60	2.52	2.32	H(3)=2.699	p=.440
Poor surface	4.57	4.70	4.42	4.52	H(3)=1.433	p=.698

Items in superscript indicate which means are significantly different from each other (Kruskal-Wallis Multiple comparisons)

4-4 Kruskal-Wallis Multiple Comparisons by Criteria based Cyclist Types

Importance of Road and Traffic Features	Heavenly	Worried	Speedy	NTI	Statistics	
Icy surface in winter	5.99 [1]	5.75	5.57	5.15 [1]	H(3)=13.175	p=.004
Traffic speed	6.23 [3,4]	6.06 [3,4]	5.37 [1,2]	4.84 [1,2]	H(3)=53.773	p=.000
Cycling facility	5.71 [3,4]	5.75 [3,4]	5.05 [1,2,4]	4.04 [1,2,3]	H(3)=60.574	p=.000
HGVs	5.54 [3,4]	5.73 [3,4]	4.79 [1,2]	4.28 [1,2]	H(3)=56.042	p=.000
Lane width	5.63 [3,4]	5.80 [3,4]	4.91 [2,3,4]	4.05 [1,2,3]	H(3)=60.589	p=.000
Off-road path	5.57 [3,4]	5.58 [3,4]	4.82 [1,2]	4.33 [1,2]	H(3)=30.449	p=.000
Traffic volume	5.66 [3,4]	5.53 [3,4]	4.74 [1,2]	4.15 [1,2]	H(3)=56.519	p=.000
Personal or area security	5.47 [3,4]	5.02 [4]	4.48 [1]	3.94 [1,2]	H(3)=43.861	p=.000
Buses	4.99 [3,4]	4.82 [4]	4.30 [1,4]	3.57 [1,2,3]	H(3)=43.861	p=.000
Surface quality	4.79 [4]	4.42	4.42	3.76 [1]	H(3)=16.059	p=.001
Scenery	4.87 [3,4]	4.73 [3,4]	3.83 [1,2]	3.90 [1,2]	H(3)=27.992	p=.000
Poor street lighting/Darkness	4.65 [4]	4.48 [4]	4.17 [4]	3.41 [1,2,3]	H(3)=30.384	p=.000
Traffic calming(20 mile zone)	4.83 [3,4]	4.66 [3,4]	3.94 [1,2,4]	3.26 [1,2,3]	H(3)=53.526	p=.000
Gradient	4.49 [4]	3.85 [4]	3.89 [4]	3.20 [1,2,3]	H(3)=28.034	p=.000
Vehicles parked on streets	4.02 [4]	4.15 [3,4]	3.57 [2]	3.10 [1,2]	H(3)=28.760	p=.000

Items in superscript indicate which means are significantly different from each other (Kruskal-Wallis Multiple comparisons)

Likelihood to choose	Heavenly	Worried	Speedy	NTI	Statistics	
Road and traffic circumstance						
Large traffic volume	3.83	3.26[3,4]	4.20[2]	4.19[2]	H(3)=17.654	p=.001
High traffic speed	2.97	2.52[3,4]	3.33[2]	3.47[2]	H(3)=19.910	p=.000
Frequently running HGVs	3.29[2]	2.69[1,3,4]	4.93[2]	4.68[2]	H(3)=29.123	p=.000
Frequently running buses	4.60	4.18[3]	4.93[2]	4.68	H(3)=14.679	p=.002
Traffic calming	5.81[3,4]	5.50	5.22[1]	5.06[1]	H(3)=19.011	p=.000
Poor personal or area security	3.42	3.04[4]	3.58	3.80[2]	H(3)=10.946	p=.012
Wide space on lane	6.57[3,4]	6.35	6.14[1]	5.94[1]	H(3)=19.439	p=.000
Moderate downhill	6.30[2,3,4]	5.85[1]	5.76[1]	5.76[1]	H(3)=16.321	p=.001
Steep uphill	4.84	4.72	4.47[4]	5.02[3]	H(3)=7.971	p=.047
Moderate uphill	5.92[3]	5.53	5.47[1]	5.58	H(3)=8.544	p=.036
Good scenery	5.65[3]	5.63[3]	4.99[1,2]	5.31	H(3)=15.885	p=.001
Parked vehicles on street	5.04	4.57	4.79	5.01	H(3)=5.830	p=.120
Poor street lighting in dark	4.17	3.71	3.89	4.19	H(3)=5.918	p=.116
Icy surface in winter	2.70	2.41	2.67	2.70	H(3)=4.030	p=.258
Narrow space on lane	4.69	4.31	4.74	4.83	H(3)=6.218	p=.101
Steep downhill	5.54	5.11	5.20	5.42	H(3)=6.507	p=.089
Poor surface	4.11	3.56	3.85	3.83	H(3)=4.115	p=.249
Good Surface*	6.01	5.95	5.75	5.61	H(3)=9.836	p=.020

Items in superscript indicate which means are significantly different from each other (Kruskal-Wallis Multiple comparisons)
* No significance is found between individual types by adjusted significance

Cycling facility	Heavenly	Worried	Speedy	NTI	Statistics	
Preference						
Cycle lane	6.57 [3,4]	6.67 [3,4]	6.20 [1,2]	5.92 [1,2]	H(3)=31.157	p=.000
Segregated cycle path	6.54 [3,4]	6.66 [3,4]	6.05 [1,2]	5.71 [1,2]	H(3)=35.350	p=.000
Off-road path	6.33 [3,4]	6.48 [3,4]	5.75 [1,2]	5.58 [1,2]	H(3)=27.739	p=.000
Cycle crossing facility	6.19 [3,4]	6.01 [3,4]	5.23 [1,2]	4.62 [1,2]	H(3)=44.697	p=.000
Bridge with a cycling only facility	6.33 [3,4]	5.93 [3,4]	5.39 [1,2]	5.20 [1,2]	H(3)=33.054	p=.000
Advanced stop line	6.24 [4]	6.12 [4]	5.83 [4]	5.30 [1,2,3]	H(3)=19.648	p=.000
Shared pedestrian path	5.29 [3,4]	5.13 [4]	4.66 [1]	4.04 [2,1]	H(3)=25.351	p=.000
On-road cycle lane	5.43	5.12	5.42	5.11	H(3)=4.122	p=.249
Shared bus lane	4.83	4.38	4.74	4.48	H(3)=4.593	p=.204
Agreement						
Continuity of cycling facility	5.73[4]	5.64	5.19	5.00[1]	H(3)=11.683	p=.009
Prefer route near to bicycle parking	5.00[4]	4.47	4.55[4]	3.78[1,3]	H(3)=22.889	p=.000
Junctions						
Behaviour						
Avoid roundabout	3.72 [4]	3.96 [4]	3.25	2.67 [1,2]	H(3)=24.618	p=.000
Avoid give-way junction	2.89 [4]	2.70 [4]	2.37 [4]	1.86 [1,2,3]	H(3)=29.127	p=.000
Avoid signalised junction	2.71 [4]	2.46 [4]	2.37 [4]	1.90 [1,2,3]	H(3)=18.999	p=.000
Avoid junction frequently used by vehicles	3.72 [3,4]	3.73 [3,4]	2.79 [1,2]	2.29 [1,2]	H(3)=49.618	p=.000
Avoid junction for right turn	3.62 [3,4]	3.61 [3,4]	2.79 [1,2]	2.35 [1,2]	H(3)=34.677	p=.000
Importance of feature						
Complexity	5.25 [3,4]	5.25[3,4]	4.66 [1,2]	4.00 [1,2]	H(3)=29.081	p=.000
Size	5.01 [3,4]	4.75 [3,4]	4.00 [1,2]	3.60 [1,2]	H(3)=39.982	p=.000
Number of vehicles making turn	4.97 [3,4]	4.89 [3,4]	4.11 [1,2]	3.51 [1,2]	H(3)=41.096	p=.000
Advanced stop line	4.97 [3,4]	5.29 [3,4]	4.17 [1,2,4]	3.14 [1,2,3]	H(3)=72.359	p=.000

Feeling unsafe	Heavenly	Worried	Speedy	NTI	Statistics	
High traffic speed	6.21 [4]	6.34 [3,4]	5.90 [2]	5.52 [1,2]	H(3)=28.021	p=.000
HGVs or buses	5.75 [4]	5.89 [3,4]	5.52 [2]	5.17 [1,2]	H(3)=21.632	p=.000
Riding without proper lights in dark	5.48 [4]	5.22	5.25	4.82 [1]	H(3)=8.367	p=.039
Large traffic volume	5.48 [3,4]	5.61 [3,4]	5.02 [2,4,1]	4.46 [1,2,3]	H(3)=44.197	p=.000
Changing lane in traffic	4.58 [4]	4.92 [4]	4.46	3.95 [1,2]	H(3)=18.691	p=.000
Making right turn at junction	4.45 [4]	4.77 [3,4]	4.19 [2]	3.83 [1,2]	H(3)=20.489	p=.000
Environment of areas nearby route	4.70 [4]	4.16	4.17	3.75 [1]	H(3)=18.533	p=.000
Not enough distance from vehicles	6.11 [3,4]	5.96	5.74 [1]	5.42 [1]	H(3)=15.003	p=.002
Vehicles parked on street	4.54 [3]	4.40	4.04 [1]	3.95	H(3)=11.690	p=.009
Steep downhill	3.57 [4]	3.34 [4]	3.24 [4]	2.68 [1,2,3]	H(3)=17.639	p=.001
Steep uphill	3.30 [4]	2.86	3.09 [4]	2.41 [1,3]	H(3)=19.700	p=.000
Moderate uphill	2.77	2.54	2.70	2.25	H(3)=7.018	p=.071
Poor surface	4.53	4.50	4.70	4.45	H(3)=0.903	p=.825
Going forward at junctions	3.47	3.39	3.34	2.95	H(3)=5.996	p=.112
Pedestrians appearing suddenly	4.96	4.87	5.06	4.75	H(3)=1.546	p=.672
Riding on road in poor weather	5.60	5.66	5.71	5.21	H(3)=6.231	p=.101

Items in superscript indicate which means are significantly different from each other (Kruskal-Wallis Multiple comparisons)

Appendix 5 Statistical Analysis of Route Evaluation Data

5-1 T-Tests of Evaluation of the Quality of Routes – Comparison by City

	Leeds	York	Sig.
Route choice criteria			
Minimising Distance*	5.0	5.7	p=.028
Minimising time*	5.1	5.8	p=.012
Safe route	4.8	4.9	p=.580
Reliable route	5.6	5.7	p=.529
Pleasant/Comfort	4.5	5.0	p=.163
Route feature			
Traffic volume*	3.4	4.5	p=.000
Traffic speed	4.0	4.4	p=.079
Lane width*	3.7	4.7	p=.001
Buses	4.2	4.5	p=.264
HGVs	4.3	4.6	p=.300
Cycling facilities*	3.4	4.9	p=.000
Vehicles parked on street*	3.8	4.8	p=.001
Main roads	3.8	4.0	p=.430
Residential roads	4.6	5.4	p=.002
Roundabouts*	3.9	4.7	p=.020
Signalised junctions*	4.3	4.9	p=.015
Give-way junctions*	4.2	5.0	p=.001
Making right turns	4.0	4.4	p=.077
Making left turns*	4.9	5.6	p=.000
Uphill*	4.0	5.4	p=.000
Downhill	5.3	5.7	p=.111
Surface*	4.0	4.9	p=.000
Scenery	4.2	4.6	p=.171
Bicycle parking*	4.6	5.5	p=.023
Pedestrian-oriented areas*	3.9	5.2	p=.001
Personal security	4.7	5.1	p=.081
Lightings (in darkness) *	4.5	5.2	p=.014

* Significance at 95%

5-2 T-Tests of Evaluation of the Quality of Routes – Comparison by Gender (Leeds)

	Male	Female	Sig.
Route choice criteria			
Minimising Distance	4.9	5.2	p=.602
Minimising time	5.1	5.0	p=.813
Safe route	4.8	4.7	p=.902
Reliable route	5.8	5.5	p=.313
Pleasant/Comfort	4.4	4.6	p=.668
Route feature			
Traffic volume	3.4	3.3	p=.852
Traffic speed	4.0	3.9	p=.653
Lane width	4.0	3.3	p=.100
Buses	4.1	4.3	p=.686
HGVs	4.1	4.5	p=.427
Cycling facilities*	4.0	2.8	p=.004
Vehicles parked on street	4.0	3.6	p=.275
Main roads*	4.3	3.3	p=.001
Residential roads	4.6	4.5	p=.753
Roundabouts*	4.2	3.6	p=.326
Signalised junctions	4.5	4.1	p=.196
Give-way junctions	4.2	4.2	p=.796
Making right turns	4.0	3.9	p=.819
Making left turns	5.0	4.7	p=.252
Uphill	4.3	3.8	p=.271
Downhill*	5.7	4.8	p=.036
Surface	4.0	3.9	p=.622
Scenery	4.2	4.1	p=.794
Bicycle parking	5.0	4.0	p=.175
Pedestrian-oriented areas	3.9	3.9	p=.995
Personal security	4.8	4.7	p=.644
Lightings (in darkness)	4.5	4.4	p=.692

* Significance at 95%

5-3 T-Tests of Evaluation of the Quality of Routes – Comparison by Gender (York)

Route choice criteria	Male	Female	Sig.
Minimising Distance	5.6	5.7	p=.641
Minimising time	5.8	5.8	p=.821
Safe route	4.8	5.1	p=.550
Reliable route	5.7	5.8	p=.523
Pleasant/Comfort	4.7	5.2	p=.236
Route feature			
Traffic volume	4.3	4.6	p=.493
Traffic speed	4.3	4.5	p=.562
Lane width*	4.3	5.1	p=.027
Buses	4.5	4.4	p=.881
HGVs	4.9	4.3	p=.156
Cycling facilities	4.8	4.9	p=.764
Vehicles parked on street	4.7	4.9	p=.630
Main roads	4.2	3.9	p=.487
Residential roads	5.3	5.5	p=.629
Roundabouts	4.6	4.8	p=.591
Signalised junctions*	4.5	5.3	p=.025
Give-way junctions	4.9	5.1	p=.568
Making right turns	4.2	4.6	p=.336
Making left turns*	5.1	6.1	p=.000
Uphill	5.3	5.7	p=.179
Downhill	5.7	5.6	p=.603
Surface	4.8	5.0	p=.531
Scenery	4.7	4.5	p=.683
Bicycle parking	5.4	5.7	p=.478
Pedestrian-oriented areas	5.0	5.5	p=.310
Personal security	5.3	5.0	p=.336
Lightings (in darkness)	5.2	5.2	p=.991

* Significance at 95%

5-4 T-Tests of Quality of Routes between Personal, Commuting, and Back-home Routes (York)

	Personal	Commuting	Backhome
Route choice criteria			
Minimising Distance*	5.9	5.6	4.0
Minimising time*	6.0	5.8	4.1
Safe route	4.9	4.9	5.0
Reliable route	5.8	5.8	5.3
Pleasant/Comfort	4.9	4.8	6.0
Route features			
Traffic volume	4.5	4.5	4.1
Traffic speed	4.4	4.5	4.4
Lane width	4.7	4.5	5.4
Buses	4.6	4.2	4.9
HGVs	4.6	4.5	5.3
Cycling facilities	5.0	4.5	5.1
Vehicles parked on street	4.8	4.6	5.4
Main roads	4.0	4.0	4.2
Residential roads	5.6	5.0	5.0
Roundabouts	4.9	4.7	4.0
Signalised junctions	4.9	5.0	5.0
Give-way junctions	5.1	4.9	4.7
Making right turns	*4.5*	*4.1*	*5.1*
Making left turns	5.7	5.5	5.7
Uphill	5.3	5.8	4.8
Downhill	5.5	5.8	5.8
Surface quality	5.1	4.5	5.0
Good scenery	4.4	4.8	4.6
Bicycle parking	5.3	6.0	5.3
Pedestrian-oriented areas	5.2	5.3	5.0
Personal security	5.2	5.0	5.3
Lightings (in darkness)	5.4	5.0	4.6

* Significance at 95% between back-home routes and personal trip or commuting routes

5-5 T-Tests of Route Quality between To-work Routes and Back-home Routes in Leeds

	To-work	Back home	Sig.
Route choice criteria			
Minimising Distance	5.8	4.5	p=.085
Minimising time*	6.1	4.5	p=.010
Reliable route	5.3	5.0	p=.736
Safe route*	6.4	5.4	p=.018
Pleasant/Comfort	4.8	5.1	p=.471
Route features			
Traffic volume	2.8	3.0	p=.679
Traffic speed	3.6	4.1	p=.346
Lane width	3.8	3.5	p=.781
Buses	3.3	3.9	p=.267
HGVs	3.4	3.5	p=.884
Cycling facilities	3.1	3.5	p=.711
Parked vehicles on street	3.4	3.4	p=1.00
Main roads	4.3	4.1	p=.876
Residential roads	4.1	4.4	p=.634
Roundabouts	3.3	2.8	p=.675
Signalised junctions	5.0	4.8	p=.642
Give-way junctions	3.8	5.0	p=.074
Making right turn	3.9	5.0	p=.831
Making left turns	4.4	5.0	p=.260
Uphill	3.5	3.5	p=1.00
Downhill*	6.0	4.5	p=.031
Surface	4.0	4.0	p=1.00
Good scenery	2.4	4.4	p=.086
Bicycle parking	5.3	4.9	p=.770
Pedestrian oriented area	3.1	3.6	p=.697
Personal security	4.6	4.3	p=.663
Lightings (in darkness)	4.9	3.9	p=.147

* Significance at 95%

5-6 T-Tests of Route Quality between To-work Routes and Back-home Routes in York

Route choice criteria	To-work	Back home	Sig.
Minimising Distance	5.5	4.0	p=.186
Minimising time	6.2	4.3	p=.107
Reliable route	4.5	4.7	p=.904
Safe route	6.0	5.2	p=.444
Pleasant/Comfort	4.7	5.8	p=.242
Route features			
Traffic volume	4.8	4.2	p=.405
Traffic speed	4.2	4.3	p=.843
Lane width	4.3	5.0	p=.501
Buses	4.7	4.5	p=.838
HGVs	5.0	5.2	p=.824
Cycling facilities	4.0	4.8	p=.462
Parked vehicles on street	4.7	5.3	p=.441
Main roads	3.8	4.2	p=.738
Residential roads	4.8	4.8	p=.974
Roundabouts	4.3	4.0	p=.780
Signalised junctions	5.0	4.8	p=.872
Give-way junctions	4.6	4.4	p=.875
Making right turn*	2.8	5.0	p=.011
Making left turns	5.6	5.8	p=.760
Uphill	5.3	4.8	p=.743
Downhill	6.3	6.0	p=.519
Surface	4.3	4.8	p=.712
Good scenery	4.2	4.5	p=.768
Bicycle parking	6.7	5.0	p=.556
Pedestrian oriented area	5.0	4.7	p=.777
Personal security	5.2	5.2	p=1.00
Lightings (in darkness)	4.0	4.2	p=.892

* Significance at 95%

5-7 T-Tests of Route Quality between Main Routes and Alternatives in Leeds

Route choice criteria	Main	Alternative	Sig.
Minimising Distance*	6.0	3.4	p=.001
Minimising time*	5.9	3.4	p=.001
Reliable route	5.7	5.3	p=.985
Safe route	5.1	5.1	p=.556
Pleasant/Comfort	4.6	5.4	p=.412
Route features			
Traffic volume	3.6	4.0	p=.641
Traffic speed	4.3	4.3	p=.964
Lane width	3.5	4.2	p=.470
Buses	4.4	5.1	p=.238
HGVs	4.3	4.9	p=.441
Cycling facilities	3.0	4.3	p=.208
Vehicles parked on street	4.0	3.7	p=.699
Main roads	3.4	4.0	p=.316
Residential roads	5.0	4.7	p=.566
Roundabouts	3.4	4.8	p=.272
Signalised junctions	4.3	4.4	p=.815
Give-way junctions	4.0	4.3	p=.628
Making right turns	3.1	3.8	p=.349
Making left turns	4.6	4.3	p=.617
Uphill	4.5	4.9	p=.671
Downhill	5.3	5.0	p=.780
Surface quality	4.0	4.0	p=1.00
Good scenery*	3.9	5.9	p=.025
Bicycle parking	4.5	5.0	p=.772
Pedestrian-oriented areas	3.8	5.0	p=.538
Personal security	4.6	5.2	p=.471
Lightings (in darkness)	4.6	3.3	p=.164

* Significance at 95%

5-8 T-Tests of Route Quality between Main Routes and Alternatives in York

	Main	Alternative	Sig.
Route choice criteria			
Minimising Distance	5.4	5.1	p=.762
Minimising time	5.4	5.0	p=.679
Safe route	5.3	4.5	p=.399
Reliable route	5.1	5.6	p=.555
Pleasant/Comfort*	6.0	3.6	p=.028
Route features			
Traffic volume	5.0	3.0	p=.061
Traffic speed	5.0	3.4	p=.133
Lane width	5.0	3.9	p=.245
Buses	4.9	3.5	p=.199
HGVs	5.4	3.6	p=.086
Cycling facilities	4.9	4.1	p=.333
Vehicles parked on street	5.3	4.4	p=.246
Main roads	4.3	2.7	p=.106
Residential roads	5.5	5.0	p=.447
Roundabouts	5.7	6.0	p=.667
Signalised junctions	5.0	4.9	p=.878
Give-way junctions	5.5	4.6	p=.292
Making right turns	4.0	4.3	p=.800
Making left turns	5.5	5.1	p=.680
Uphill	5.8	5.8	p=1.00
Downhill	5.6	6.0	p=.568
Surface quality	4.6	5.3	p=.247
Good scenery*	6.4	3.6	p=.001
Bicycle parking	6.0	6.0	p=1.00
Pedestrian-oriented areas	5.8	4.3	p=.115
Personal security	5.2	5.0	p=.839
Lightings (in darkness)	4.5	6.5	p=.083

* Significance at 95%

Appendix 6 Statistical Analysis of Route Evaluation Data

6-1 Information of Participants of GPS Survey and Interviews

Participant	City	Gender	Age	Confidence level	Criteria type
L1	Leeds	Female	35-44	Unconfident	Speedy
L2	Leeds	Female	35-44	Beginner	Heavenly
L3	Leeds	Female	45-54	Confident	Heavenly
L4	Leeds	Male	25-34	Confident	NTI
L5	Leeds	Male	25-34	Very confident	Heavenly
L6	Leeds	Female	25-34	Unconfident	NTI
L7	Leeds	Female	35-44	Very confident	Heavenly
L8	Leeds	Male	55-64	Beginner	Speedy
L9	Leeds	Male	45-54	Confident	Speedy
L10	Leeds	Female	25-34	Beginner	Worried
L11	Leeds	Male	35-44	Confident	Speedy
L12	Leeds	Female	35-44	Confident	Worried
L13	Leeds	Male	25-34	Confident	Speedy
L14	Leeds	Male	55-64	Beginner	Worried
L15	Leeds	Male	25-34	Unconfident	Worried
L16	Leeds	Male	35-44	Unconfident	NTI
L17	Leeds	Male	25-34	Confident	Speedy
L18	Leeds	Female	45-54	Very confident	NTI
L19	Leeds	Female	55-64	Unconfident	Heavenly
L20	Leeds	Male	45-54	Very confident	NTI
L21	Leeds	Female	25-34	Confident	NTI
L22	Leeds	Male	45-54	Very confident	NTI
L23	Leeds	Male	18-24	Confident	NTI
L24	Leeds	Male	25-34	Unconfident	Speedy

Participant	City	Gender	Age	Confidence level	Criteria type
Y1	York	Male	55-64	Confident	Speedy
Y2	York	Male	45-54	Unconfident	NTI
Y3	York	Female	18-24	Unconfident	Speedy
Y4	York	Male	45-54	Unconfident	NTI
Y5	York	Female	35-44	Confident	Worried
Y6	York	Male	25-34	Very confident	Heavenly
Y7	York	Male	45-54	Very confident	NTI
Y8	York	Female	25-34	Confident	NTI
Y9	York	Female	25-34	Unconfident	NTI
Y10	York	Male	45-54	Confident	NTI
Y11	York	Male	35-44	Confident	Speedy
Y12	York	Female	45-54	Confident	Worried
Y13	York	Male	55-64	Unconfident	Worried
Y14	York	Male	55-64	Confident	Speedy
Y15	York	Female	35-44	Very confident	Speedy
Y16	York	Male	45-54	Very confident	Heavenly
Y17	York	Female	35-44	Unconfident	Speedy
Y18	York	Male	45-54	Very confident	Worried
Y19	York	Female	45-54	Confident	Worried
Y20	York	Male	55-64	Confident	Speedy
Y21	York	Female	55-64	Beginner	Worried
Y22	York	Female	55-64	Very confident	Heavenly
Y23	York	Female	45-54	Confident	Heavenly

6-2 Schedules of GPS Survey

	Start	End	Participants						
Week 1	09-Jul-2012	13-Jul-2012	L12	L17					
Week 2	16-Jul-2012	20-Jul-2012	L1	L6	L10				
Week 3	23-Jul-2012	27-Jul-2012	L5						
Week 4	30-Jul-2012	03-Aug-2012	L11	L16	Y17	~~*L25*~~			
Week 5	06-Aug-2012	10-Aug-2012	L8	L21	Y11	Y23			
Week 6	13-Aug-2012	17-Aug-2012	Y6	Y9					
Week 7	20-Aug-2012	24-Aug-2012	L4	L7	L15	Y1			
Week 8	27-Aug-2012	31-Aug-2012	L2	L14					
Week 9	03-Sep-2012	07-Sep-2012	L22	Y5	Y13				
Week 10	10-Sep-2012	14-Sep-2012	L3	L9	~~*L26*~~				
Week 11	17-Sep-2012	21-Sep-2012	L19	Y3	Y8	Y12	Y14	Y15	Y20
Week 12	24-Sep-2012	28-Sep-2012	L18	L20	L23	Y7	~~*L27*~~		
Week 13	01-Oct-2012	05-Oct-2012	Y4	Y21					
Week 14	08-Oct-2012	12-Oct-2012	Y16	Y19					
Week 15	15-Oct-2012	19-Oct-2012	L13	Y10	Y22				
Week 16	22-Oct-2012	26-Oct-2012	L24	Y2	Y18				

~~*Number*~~ : Participants who did not attend at an interview session

6-3 Schedules of Interviews

Time	26/11/2012(Mon)	27/11/2012(Tue)	27/11/2012(Wed)	28/11/2012(Thu)	28/11/2012(Fri)
10.00					
11.00					
12.00					
13.00					
14.00	L1		L3		L5
15.00					
16.00	L2			L4	L6
17.00					
18.00					
19.00					

Time	03/12/2012(Mon)	04/12/2012(Tue)	05/12/2012(Wed)	06/12/2012(Thu)	07/12/2012(Fri)
10.00					
11.00					
12.00				L11	
13.00					
14.00	L8		L10		L12
15.00					
16.00					
16.30					
17.00	L7		L9		
18.00					
19.00					

Time	10/12/2012(Mon)	11/12/2012(Tue)	12/12/2012(Wed)	13/12/2012(Thu)	14/12/2012(Fri)
10.00				Y4	
11.00					
12.00				Y5	
13.00			Y2		
14.00				Y6	
15.00					
16.00	Y1		Y3	Y7	
17.00					
18.00					
19.00					

Time	17/12/2012(Mon)	18/12/2012(Tue)	19/12/2012(Wed)	20/12/2012(Thu)	21/12/2012(Fri)
10.00					
11.00					
12.00					
13.00					
14.00			Y8		
15.00					
16.00			Y9		
17.00					
18.00			Y10		
19.00					

Time	07/01/2013(Mon)	08/01/2013(Tue)	09/01/2013(Wed)	10/01/2013(Thu)	11/01/2013(Fri)
10.00				Y15	
11.00					
12.00				Y16	
13.00					
14.00	Y11		Y12	Y17	
15.00					
16.00			Y13		
17.00					
18.00			Y14		
19.00					

Time	14/01/2013(Mon)	15/01/2013(Tue)	16/01/2013(Wed)	17/01/2013(Thu)	18/01/2013(Fri)
10.00		Y20			
11.00					
12.00		Y21		Y23	
13.00					
14.00	Y18	Y22			
15.00					
16.00					
17.00	Y19				
18.00					
19.00					

Time	21/01/2013(Mon)	22/01/2013(Tue)	23/01/2013(Wed)	24/01/2013Thu)	25/01/2013(Fri)
10.00					
11.00				L14	
12.00					
13.00				L15	
14.00			L13		
15.00					L16
16.00					
17.00					
18.00					
19.00					

Time	28/01/2013(Mon)	29/01/2013(Tue)	30/01/2013(Wed)	31/01/2013(Thu)	01/02/2013(Fri)
10.00				L21	
11.00					
12.00				L22	
13.00		L18			
14.00				L23	
15.00			L20		
16.00					
17.00	L17				L24
18.00			L19		
19.00					