The intention to cycle: A comparative study of the perceptions and attitudes of cyclists and non-cyclists

James O'Hare

A thesis submitted for the degree of Doctor of Philosophy

in the

School of Engineering

NEWCASTLE UNIVERSITY

September 2018

Abstract

This research aims to inform policy to increase utility cycling which, it has been suggested, delivers health benefits alongside reduced congestion and improved quality of life. Previous quantitative research has addressed measurable aspects of journeys (e.g. travel time and cost) for use in transport models and scheme evaluation, while qualitative research has helped identify other important issues (such as attitudes and perceptions). However, further research was required, in particular further investigation of differences between the attitudes of those that cycle and those that currently do not. This study addresses this research gap by i) collecting individual level responses from a large cross-sectional sample sample (n=3807) of cyclists and non-cyclists about their attitudes and perceptions while ii) addressing journeys beyond the commute and iii) combining this data with an objective measure of the cycling environment in order to increase current knowledge on factors influencing the decision to cycle. Data were collected in two waves (September 2015 and February 2016). Descriptive analysis is used to explore the responses to attitudinal statements while path modelling, within which the statements are grouped into theory-led constructs, helped elucidate issues influencing the intention to cycle.

As the first to apply Partial Least Squares - Structural Equation Modelling using a relatively large sample to cycling specific research, this study contributes to the application of Structural Equation Modelling methods in this field. The path modelling performed best for more frequent cyclists, identifying convenience as the most important construct for this group. Attitudes towards cycling were found to be the most important for non-cyclists. Both descriptive and path modelling analyses found issues surrounding safety while cycling on the road and personal security to be more important for female respondents. Although all groups had generally poor perceptions of the cycling environment, male cyclists were more likely to have positive perceptions with female non-cyclists most likely to have negative perceptions.

Segmentation analysis identified four classes which can be compared to Geller's 'Four Types of Cyclist'. However, the newly proposed cateogrisation separates out those that are 'interested but concerned' from 'concerned cyclists' highlighting that many existing cyclists may be cycling despite their concerns rather than because of their positive perceptions. This can be seen in both the results of the attitudinal and path

modelling analysis and this triangulation highlights the benefits of combining these methods, allowing for more strength in this conclusion. While safety is confirmed as a concern for all groups, the perceived convenience of cycling is also revealed to be important relative to other aspects and thus it is recommended that policies addressing this issue are brought forward. The issues which most affect female cyclists must be addressed to achieve the gender balance in participation levels seen in countries with high levels of cycling.

Acknowledgements

I would like to thank the Engineering and Physical Sciences Research Council (EPSRC) and the Department for Transport (DfT) that provided funding for the PhD Studentship. I would also like to thank Dr. Neil Thorpe, Dr. Anil Namdeo and Prof. Margaret Bell for their help and supervision and the DfT staff who provided guidance across the research project – particularly Andrew Scott.

Finally, I would like to thank my friends and family for their support and putting up with me through the ups and downs. I would especially like to thank my dad and Anna, my wife. I couldn't have done this without you.

Contents

List of Figures

List of Tables

List of Abbreviations

ANOVA Analysis of Variance

AVE Average Variance Explained

CB-SEM Covariance Based - Structural Equation Modelling

DfT Department for Transport

ESOMAR European Society for Opinion and Market Researching

EU European Union

GHG Greenhouse Gas

GLS-SEM Generalised Least Squares - Structural Equation Modelling

GoF Goodness of Fit

GPPAQ General Practitioner Physical Activity Questionnaire

HEAT Health Economic Assessment Tool

HGV Heavy Goods Vehicle

IP Internet Protocol

ISA Importance-Satisfaction Analysis

LCDS London Cycle Design Standards

LSOA lower super output areas

MAMIL Middle-aged man in Lycra

NCS National Cycling Strategy

NS-SEC National Statistics Socio-economic Classification

NTS National Travel Survey

ONS Office for National Statistics

pct The Propensity to Cycle tool

PLS Partial Least Squares

PLS-MGA Partial Least Squares - Multigroup Analysis

PLS-SEM Partial Least Squares - Structural Equation Modelling

REBUS Response Based Unit Segmentation

SEM Structural Equation Modelling

TfL Transport for London

TPB Theory of Planned Behaviour

TRID Transport Research Integrated Database

UK United Kingdom of Great Britain and Northern Ireland

USA United States of America

WebTAG Transport Appraisal Guidance

WTP Willingness to Pay

Dedicated to my mum…

Chapter 1. Introduction

1.1 Aim

A broad population engaged in utility cycling is necessary to increase cycling levels substantially and maximise the benefits to society, the environment and individuals. The aim of this thesis is to add to the existing knowledge base on the impact of attitudes and perceptions on the intention to cycle for utility purposes. Through achieving this aim the research will be able to help inform policy decisions to enable a broader population to cycle for utility purposes than is currently found in countries with low cycling mode shares, such as the UK.

Alongside the production of this thesis, this research was also required to produce results which could inform a policy document for the Department for Transport (DfT). The research described in this thesis was carried out independently and recommendations of the author do not constitute a policy decision by the DfT.

1.2 Benefits of Cycling

In the 2008 Climate Change Act the UK committed to reduce its Greenhouse Gas (GHG) emissions by 80% from a 1990 baseline by 2050 (Great Britain, 2008). Motorised road transport accounted for 20% of all domestic GHG emissions in 2009, this has increased as a proportion of overall emissions as other sectors have reduced their emissions levels (Statistics, 2010).

Air pollution presents a further environmental challenge with motorised transport contributing to air quality problems, particularly in city centre areas (Giles-Corti et al., 2016). While developments in the efficiency of combustion engines, pushed forwards through the European Union (EU) 'Euro' regulation scheme (European Environment Agency, 2013) and the development of electric cars (Bilotkacha and Mills, 2013) which do not produce vehicle-level emissions, can help to mitigate the issue, a range of solutions is needed to tackle these joint challenges. Modal shift from car to non-motorised modes for utility journeys, such as commuting journeys or 'trips to the shop', is an essential element of the UK Government's policy to meet this challenges as stated in the Department for Transport's Door to Door strategy (Department for Transport, 2013b).

Alongside the environmental benefits, utility cycling provides an opportunity to integrate physical activity into everyday life. Modelling by Woodcock, Givoni and Morgan (2013) has shown that increasing the level of cycling in the UK would benefit individuals, through increased longevity of life and also that the burden on the NHS would be lessened through the reduction of cardio-vascular and other diseases, such as some cancers which are linked to physical inactivity. The World Health Organisation's Health Economic Assessment Tool (HEAT) is intended to facilitate estimating the economic value of reduced mortality that results from walking or cycling. For example, it has been used to calculate that significant health and economic benefits would accrue from the construction of a new cycleway (Deenihan and Caulfield, 2014).

While there are significant health benefits which can be gained from cycling it is important to acknowledge the risks. Cyclists have a relatively high risk of being killed or seriously injured per kilometre travelled in comparison to car drivers (Department for Transport, 2014a). Also, partly due to the increased rate of breathing, cyclists can be exposed to high levels of air pollution (Hartog et al., 2010). Several studies have attempted to balance the benefits against the risks from a health perspective and have concluded that the benefits outweigh the risks in most situations and that short journeys are always beneficial except where pollution levels are extremely high (Hartog et al., 2010; Oja et al., 2011).

If programmes to increase the levels of cycling also achieve modal shift away from cars in an equitable manner, these benefits could be seen alongside reduced congestion, improved air quality and increased mobility for those that do not have access to a car (Jones and Lucas, 2012).

In city centres where the space available to cater for current or increased levels of motor traffic and parking is limited, cycling also provides a space-efficient mode of transport. Examples of this can be seen in London where cycling levels have increased in recent years (Aldred and Dales, 2017; Lam, 2017).

While evidence for the many benefits of increasing the proportion of journeys is constantly developing many of the key arguments are long established (Department of Transport, 1996; Department for Transport, 1999). Despite this in many developed countries cycling levels have not recovered from the post-war decline associated with the increased ownership and use of private cars (Aldred, 2010).

As the extent of the health and environmental issues becomes clear interest in cycling at a policy level has increased in recent years. It is important that policy makers and transport planners have the right evidence to ensure that the policies implemented do not repeat the mistakes of the past and enable the development of physical and social environments which enable a growth in cycling across the population, realising the potential benefits for individuals and at a societal level.

1.3 International Context

A study conducted in the United States of America (USA) and Canada by Pucher, Buehler and Seinen (2011), using data from the National Personal Transportation Survey, found a similar pattern to that described by Goodman (2013) in the United Kingdom of Great Britain and Northern Ireland (UK) census data (see Section 1.5.3, with a 'bicycling renaissance' having occurred in the 2000s, but again finding that the increases had been limited to a cluster of cities and towns. This study also found that the gender gap in cycling levels had actually grown where cycling mode share had increased.

The histories of Anglophone western countries such as the UK and the USA sit in contrast to the recreation of cycling cultures which has been seen in countries in continental North-western Europe such as Denmark, Germany and the Netherlands. Cycling mode share for these countries is shown in Table 1.1, with Great Britain and the USA included for comparison. The data used are from the mid-2000s and were compiled for the European Parliament.

Country	Bicycle Mode Share (%)
The Netherlands	26
Denmark	19
Germany	10
Great Britain	2
USA	1

TABLE 1.1: Bicycle Mode Share – All Journeys (TRT and European Parliament's Committee on Transport and Tourism, 2010)

Similar to the UK, these European countries all experienced decreases in the level of cycling in the post-war period as the transport policies moved towards the promotion of the private car, however in the 1970s the policy shifted, particularly in the Netherlands following the change in public mood which was expressed through the 'stop de kindermoord' campaign in response to the death of children in road collisions and the formation of the Dutch Cyclists Union (Fietsersbond). This was supported by, and influenced, a change in transport policy moving away from catering for the car at the expense of other modes and towards developing safe and convenient bicycle infrastructure in towns and cities. Through these measures the decline in cycling levels was halted and reversed (Welleman, Ministry of Transport Public Works and Water Management and Concorde Vertalingen BV, 1999; Stoffers, 2012).

While there are variations in the level of cycling within these countries, in general the level of cycling is higher than all but a few places within the UK. The cycling population is much more diverse, with equality between genders and high levels of cycling within older age groups (Pucher and Buehler, 2008). A key indicator of the success of the cycling policies is the safety of cycling, with incidents/km cycled providing the most appropriate and comparable measure. By this measure the Denmark, Netherlands and Germany are generally much safer than the UK or USA as shown in Table 1.2.

	Cyclists Killed (per 1x10^8 km Cycled)	Cyclists Injured (per 1x10^7 km Cycled)
Netherlands	1.0	1.0
Denmark	1.4	1.2
Germany	1.5	3.4
UK	3.3	4.3
USA	5.3	26.8

TABLE 1.2: Fatality rates and non-fatal injury rates in the Netherlands, Denmark, Germany, the UK and the USA (2004–2005) Expressed relative to Netherlands figures (Adapted from (Pucher and Buehler, 2008))

Pucher and Buehler (2008) summarise the importance of safety and the segregated cycling infrastructure and changes to road design which have created safe environments in their influential work - Making Cycling Irresistible, Lessons from The Netherlands, Denmark and Germany.

> "The most important approach to making cycling safe and convenient in Dutch, Danish and German cities is the provision of separate cycling facilities along heavily travelled roads and at intersections, combined with extensive traffic calming of residential neighbourhoods. Safe and relatively stress-free cycling routes bare especially important for children, the elderly, women and for anyone with special needs due to any sort of

> disability. Providing such separate facilities to connect practical, utilitarian origins and destinations also promotes cycling for work, school and shopping trips, as opposed to the mainly recreational cycling in the USA, where most separate cycling facilities are along urban parks, rivers and lakes or in rural areas." Pucher and Buehler (2008, p. 53)

Harms, Bertolini and Brömmelstroet (2015) addressed a knowledge gap in the history of the Netherlands as a cycling nation by trying to assess the relative importance of the infrastructure measures described above alongside other factors such as demographics, land use, cycle education and governance. This study uses data collected from a survey of civil servants responsible for coordinating cycle policy and volunteers from the Dutch Cyclists' Union (Fietsersbond). Despite the limitations of the data, which rely on the perceptions of a small number of respondents who may not be objective about their cities, this study does offer some insight on the question. The respondents were asked about their perceptions of their city's hardware (infrastructure), software (education) and orgware (organisation and implementation) and this information was combined with demographic and spatial data about the cities using a Rough Set Approach. This study, found that a combination of cycling infrastructure, steps to reduce the attractiveness of car use and strong leadership and organisational structures was important in cities which had higher levels of cycling. Additionally, this study found links between educating children about the benefits of cycling and providing child cycle training and a high perception of safety and citizen participation in policy. The provision of cycle education programmes for adults was associated with a good perception of cycling conditions. The paper also notes the difficulty of generalising the findings, especially on the importance of educating adults, to other locations which do not have an established cycle culture and practice. This is particularly relevant to the UK as 'smarter measures' such as cycle training for adults have become increasingly popular since a change in emphasis in the early 2000s (Golbuff and Aldred, 2012).

1.4 Cycling in England: historical trends

In order to set the background for this research on barriers and attractors for current cyclists and non-cyclists it is useful to place the current UK cycling landscape in an historical context.

1.4.1 *UK Data Sources*

There are a number of data sources that provide useful historical data on cycling. The three most commonly used are the National Travel Survey (Department for Transport, 2016c), the Local Area Walking and Cycling statistics (Department for Transport, 2016b), and the Census data on the method of travel to work(Office for National Statistics, 2014).

Census: This is carried out every 10 years (each year ending with a 1). The data are held by the Office of National Statistics. The census provides an excellent resource which includes a question on usual method of travel to work. It provides high geographical and demographic resolution, with excellent population coverage, including for hard to reach groups. However, it is only an occasional snapshot of behaviour, with a low frequency of collection and it does not include cycling as part of a journey.

National Travel Survey (Department for Transport, 2016c): This provides comparable data on how and why people travel. Data are available from 1995/7 onwards on an annual basis. This survey allows a comparison of cycling levels since the launch of the National Cycling Strategy in 1996 (Department of Transport, 1996). The survey is carried out by Department for Transport.

Local Area Walking and Cycling Statistics (Department for Transport, 2016b): Published out by the Department for Transport on an annual basis.

Active People Survey (Sport England, 2016): Carried out on behalf of Sport England it is designed to capture general participation in sport.

Other useful data sources include **Transport Statistics Great Britain** held by Department for Transport (Department for Transport, 2016d) and the **National Cycle Network Annual Usage Estimate** (Sustrans, 2014a) carried out by Sustrans.

Because of the unrivalled coverage, the census is a particularly important source. However, as with each source there are some problems with using census data. It is only collected every 10 years Office for National Statistics, 2011a and, with the last Census taking place in 2011, the most recent data available is 7 years old at the time of writing. However, as the question used in the questionnaire is “How do you usually travel to work?” and only the mode used for the longest distance is recorded for mixed mode journeys, it does not include people that cycle occasionally or for only part of their commute.

A more philosophical criticism of relying the Census data, when discussing levels of cycling, is that it may encourage a narrow focus on commuting while ignoring current and potential cycling journeys made for other purposes. The focus on the commute in transport planning has been criticised as commuting makes up a smaller proportion of trips made by younger people, older people and women (Department for Transport, 2016c, Table 0611). Women are more likely to make journeys with children or chained trips (Aldred, Woodcock and Goodman, 2015) which may be more difficult to make by bike compared to 'unencumbered' journeys.

While it is important to acknowledge its weaknesses, the Census data provides a level of detail and historical reach which is hard to replicate using other sources. Several investigations have been conducted using Census data to explore changes in commuting levels by bike over time (Parkin, 2003; Goodman, 2013).

As there is not one overall measure it is necessary to use different sources and so to refer to different measures of the level of cycling throughout this section. For instance, the Census data refers the usual main mode of travel for a commuting journey while the most comparable measure in the Active People survey (Sport England, 2016) is referred to as total participation time. Where possible, comparable measures are used when discussing a particular issue.

1.4.2 *Trends in the 20th Century*

Cycling currently accounts for 2% of all journeys in England, according to the 2015 National Travel Survey (Department for Transport, 2016c). This is a low level compared to the pre-motorway era, with levels peaking in 1949 when 37% of all journeys were made by bike (Horton, Rosen and Cox, 2007). From 1950 the level of cycling dropped steeply in the 1950s through to the mid-1970s before the decline stopped in the mid-1970s when the average distance cycled per person was around 20% of the 1950 level (Department for Transport, 2017). Following the steep decline there have been some periods of growth and other periods of a shallower decline, but the overall level of cycling has remained similar since the mid-1970s.

The National Travel Survey (Department for Transport, 2016c) allows a comparison of cycling levels since the launch of the National Cycling Strategy in 1996 (Department of Transport, 1996) which set targets the number of cycling trips to be doubled by 2002 and doubled again by 2012. Reviewing the National Travel Survey data shows that these targets were not reached, with the number of cycling trips per person down

8% since 1995/7 (see Section 1.5.2). This fall sits alongside an overall drop in the number of trips made by any mode (Department for Transport, 2016c).

An alternative measure of the level of cycling available from the National Travel Survey is distance, and there has been an increase of 26% in the distance cycled per person since 1995/7, indicating that there has been some increase in this measure since the National Cycling Strategy was released.

Indeed, while these figures suggest that there hasn't been a significant increase in the level of cycling nationally there have been more noticeable increases in some parts of the population. Due to the size of the dataset, the Census method of travel to work data is a useful source when looking at long term trends in cycling if the aim is to compare population groups or locations. Despite the limitations of Census data, a comparison of the National Travel Survey and Census data found that there was a 0.77 correlation between the proportion of adults that choose cycling as their usual commute mode (from Census data) and the modal share of cycling as a proportion of total travel time (from National Travel Survey (NTS) data), despite commuting accounting for only 31% of the cycling travel time reported (Goodman, 2013).

Parkin (2003) used Census data from 1971 to 2001 to look at long term trends in the proportion of commuting journeys made by bike at a national level and identify patterns at a regional and district level. In this paper, Parkin concludes that there was a decline in the level of cycling to work in the 1980s, but finds no significant difference in the level of cycling between 1991 and 2001. This is interpreted as suggesting that the decline has stopped, with 2.9% of journeys to work made by bike in 2001. Cambridge is identified as a district which has had consistently high levels of cycling, with slight growth from 1971-2001. At the same time, other districts with greater than 6% cycle mode share in 2001, such as York, Oxford and Hull, had generally seen small declines in cycling mode share since 1971.

In the same paper, Parkin (2003) notes the issues with Census data described earlier and so uses other datasets to supplement the Census data. Using estimates of the total distance cycled (DfT Transport Statistics), Sustrans and data on personal levels of cycling from the National Travel Survey, Parkin notes a contrasting pattern in which the estimated distance cycled is reported to have increased but the average level of cycling per person has decreased. While Parkin makes clear that monitoring changes could partly explain the increase in the estimate of the total distance between 1993 and 2002, it is not clear whether population growth has been considered in this comparison.

Looking at the most recent Census data from 2011, it appears that the levelling off described by Parkin appears to have continued between the 2001 and 2011, with the proportion of working residents cycling to work reported as 2.8% in 2011 (Office for National Statistics, 2014). In a similar fashion to Parkin's 2003 paper, Goodman (2013) conducted a detailed comparison of bike commuting using the most recent census data available at that time. In addition to the national and regional comparisons conducted by Parkin the more recent Goodman paper also used data from the Indices of Multiple Deprivation to characterise socio-economic patterning in cycling levels.

In summary, these studies suggest that though there is uncertainty due to the difficulty of consistently measuring cycling participation, the overall level of cycling has not changed noticeably at a national level since the decline in cycling levels during the 1980s.

1.5 The Impact of Cycling Policy in the UK

The study of UK cycling levels in a historical and international context shows that it cannot be taken for granted that interventions to increase cycling levels will lead to balanced cycling growth across the population, but also highlights that in countries with higher levels of cycling rates are more equal across age and gender as discussed in Section 1.3. This reinforces the importance of understanding the needs of different demographic groups to ensure that interventions to ensure that cycling interventions do not simply reinforce existing privileges without benefiting those that may benefit most from the health benefits and accessibility which cycling has the potential to provide.

1.5.1 *False Starts*

Golbuff and Aldred (2012) provide a historic and thematic overview of cycling policy in the UK, focussing on the post motorway period from the 1970s and finishing with an overview of the 2010 coalition Government's early statements and actions around cycling policy. This review reveals several 'false starts' during this period within which ambitious targets were set for increased levels of cycling but not reached despite apparent initial enthusiasm.

In their analysis of how cycling policy and actions developed Golbuff and Aldred (2012) suggest that the reason that these targets were not met is due a mismatch between the intent to increase cycling levels and the implementation of policy to achieve this aim. From the 'false starts' of the 1970s through to the 2000s, a repeated theme is that the 'spend per head' set out in the spending commitments is below the level required to meet the ambitious targets. They also draw attention to a lack of central leadership required to prioritise sustainable modes and to reduce private car usage. On the other hand, there is some optimism in the evolution of cycling as mainstream within UK policy through the establishment of the National Cycle Network and Cycling Strategies, alongside a shift in focus towards the cost effectiveness and health benefits of cycling. Further optimism can be found in the link between areas which have increased their spend per head through short-term schemes, such as the Cycling Demonstration towns (Cycling England, 2009), or longer term investment in the case of London (Transport for London, 2013) and an increase in cycling mode share.

1.5.2 *The National Cycling Strategy and Cycling and Walking Investment Strategy*

Published 20 years apart, the 1996 National Cycling Strategy (NCS) (Department of Transport, 1996) and the 2016 Cycling and Walking Investment Strategy (Department for Transport, 2016a) are two of the most significant points in the integration of cycling into UK transport policy. The 1996 Cycling Strategy followed the creation of the National Cycle Network in 1995 (Golbuff and Aldred, 2012) and set out core strategies backed up by specific outputs linked to increasing cycle usage. The first Cycling and Walking Investment Strategy was released in 2016 following the integration of cycling into the Infrastructure bill for the first time and set out the vision for cycling policy in light of the increasing devolution of powers away from Westminster (Department for Transport, 2016a). The core target of the NCS was to double the number of cycle trips by 2002 and to double it again by 2012 (Department of Transport, 1996). Assuming these trips replaced trips by other modes, this would have resulted in a cycle mode share of between 7.6% and 8.3% in 2012, depending on whether trips is defined as per person or total cycle trips accounting for population change.

A paper considering these targets, published in 1997, found that segregated infrastructure would have to be deployed on a 'massive scale' in order to achieve this target (Wardman, Hatfield and Page, 1997, p.132). The finding was based on a stated preference study which indicated that unsegregated infrastructure would not lead to sufficient change in mode choice. The study concluded that this infrastructure would have to be combined with significant restrictions on car use and other measures to

	1996	2012 (actual)	2012 (projected, per person)	2012 (projected, total trip)
Trips per person	20	16	80	71.8
Mode Share (%)	1.7	1.7	8.3	7.6

TABLE 1.3: Implied mode share from trip based UK targets included in 1996 National Cycling Strategy - calculated using data from ONS population estimates, NCS and NTS data.

achieve the targets (Wardman, Hatfield and Page, 1997). These targets were not met with the number of cycle trips per person per year actually falling slightly from 20 to 16 (Department for Transport, 2013c).

A review of local cycle strategies found that local authorities had been slow to adopt the aims and best practice put forward in the NCS (Lumsdon and Tolley, 2001). The authors concluded that, given the importance of orgware (organisational structures and commitment from leadership) found in the Dutch context and the need for significant changes to meet the targets, this lack of leadership at a local level, combined with the low level of funding provided given the changes needed made it very difficult for the ambitious targets to be met.

The 2016 Cycling and Walking Investment Strategy resets the aim of doubling the number of walking and cycling trips, with a new target date of 2025 (Department for Transport, 2016a). This medium term aim is supplemented by a longer term ambition to make cycling and walking the 'natural choice' for short trips by 2040. The updated target now refers to stages rather than whole trips, meaning it is difficult to establish the resultant modal share due to the amount of confounding variables, such as changes in the overall number of trips and changes in population. However, taking central population estimates the proportion of trip stages made by bike could be expected to be between 2.6% and 3.0% depending if the target is achieved, compared to 1.5% from the 2013 baseline (values calculated from data obtained in (ONS, NTS, Transport Statistics). Through achieving this target it would also be expected that the mode share for commuting journeys would be expected to double from 3% to 6%. As described by Lovelace et al. (2016, p. 12) this change is 'substantial in relative terms' but the level would remain 'low compared with countries such as the Netherlands and Denmark'.

The Propensity to Cycle Tool models which commuting journeys could be moved to bike trips under different scenarios (Lovelace et al., 2016). Exploring different scenarios using the tool highlights that many urban areas will have to have cycling levels of over 10% alongside smaller increases in rural areas for this national target to be met. The tool could help local planners translate national targets into local aspirations, an issue which is likely to become increasingly important alongside increasing devolution.

1.5.3 *Geographical Variation*

Evidence suggests that though some increases in cycling levels have occurred between the 2001 Census and 2011 Census they were not geographically widespread or evenly distributed across society, with Central London seeing the strongest growth (Goodman, 2013). Goodman (2013) had already identified Hackney as the district with the highest proportional growth between 1991 and 2001, but reported that the growth in that district to 2011 was even steeper, at 8.5 percentage points. Interestingly, many of the other districts with high levels of cycling which had seen a slight fall between 1971 and 2001 showed a slight increase between 2001 and 2011. Large increases were seen in inner London, meaning that London (2001: 2.3% 2011:3.9%) overtook East of England (3.9% 2011:3.4%) as the region with the highest cycling mode share (Office for National Statistics, 2014). However, these localised increases have not led to a national increase as cycling levels remained level or decreased in other areas of the country. It is important to understand why cycling is increasing in some areas and not others to determine future policy decisions and evaluate past choices to determine whether policy may have unintentionally helped to help the already privileged rather than helping to rebalance existing inequalities.

In order to highlight the areas which have the highest consistent levels of cycling figures for 1981 to 2011 for those districts where 10% or more of cycling journeys were made by bike in 2011 are shown in Table 1.4.

Local Authority	1981 (%)	2011 (%)	Percentage Point Change
Cambridge	27.6	29.0	1.4
Oxford	20.3	17.1	-3.2
York	21.0	11.2	-9.8
Gosport	14.7	10.7	-4.0

TABLE 1.4: Local Authority districts with 10% or more commuting journeys made by bike in both 1981 and 2011 Census – adapted from (Parkin, 2003)

1.5.4 *Social Variation*

Nationally between the 2001 and 2011 censuses the proportion of working residents cycling to work remained at 2.8% (Office for National Statistics, 2014). Goodman's 2013 socio-demographic analysis showed that cycling to work has historically been more common in less affluent areas, however she argues that this is now inverted in England's highest-cycling areas (Cambridge, Oxford and Hackney) (Goodman, 2013). In this analysis, cyclists were more likely to live within less deprived areas of the local authority. This finding reflects a wider trend in which cycling has moved from being a poor person's form of transport to one that is increasingly a symbol of middle class lifestyles. The extent to which this can reflect gentrification of poor areas has been discussed both in the UK and internationally (Aldred and Jungnickel, 2014; Hoffmann and Lugo, 2014). Goodman's socio-demographic analysis showed that cycling to work has historically been more common in less affluent areas, however she argues that this is now inverted in England's highest-cycling areas (Cambridge, Oxford and Hackney) (Goodman, 2013). In this analysis, cyclists were more likely to live within less deprived areas of the local authority. This finding reflects a wider trend in which cycling has moved from being a poor person's form of transport to one that is increasingly a symbol of middle class lifestyles. The extent to which this can reflect gentrification of poor areas has been discussed both in the UK and internationally (Aldred and Jungnickel, 2014; Hoffmann and Lugo, 2014).

The pattern of cycling having increased in already privileged groups is borne out in research which has been conducted to examine the potential for cycling in London. Transport for London (TfL) found that increases in the number of cycling trips in London during the 2000s was largely due to existing cyclists cycling more often rather than an increase in the number of cyclists, with the majority of frequent cyclists being within the 25-44 white male cohort and on a higher than average income (Transport for London, 2011). TfL research into the potential for cycling in London found that there was further potential for an increase in cycling levels within this demographic group, but also found that there was significant potential for growth to create modal shift across the population (Transport for London, 2010). Encouraging new cyclists is particularly important as groups with lower levels of cycling are also less likely to meet physical activity guidelines and suffer from social issues such as poor access to services (Long et al., 2009).

1.5.5 *Male Female Variation*

A further study of the Census method of travel to work data was conducted by Aldred, Woodcock and Goodman (2015) who reviewed proportion of commuting trips made by bicycle and also compared data for 2001 and 2011. This analysis found that, in Local Authorities where cycling mode share had increased during the 2000s, the gender gap had not reduced, with men still being twice as likely to cycle to work as women. The same study also found that there was a decreased representation of older cyclists in the cohort. This suggests that, while the numbers of female and older cyclists are increasing, the rate of increase is not quicker, and in some cases may even be slower, than the rate of increase for white males.

1.6 Objectives

The aim of this thesis is as stated in Section 1.1. In order to achieve this aim, the objectives of the project are to:

1. Review the existing literature and refine the aim to address research gaps within the available cycling literature relating to barriers and attractors to broader participation in utility cycling.
2. Develop a research plan based on the identified research gap which can add to the body of existing knowledge and provide outputs which are useful in informing policy.
3. Carry out exploratory and pilot research to refine the tools and methods ensuring that the chosen methods are appropriate and suitable for achieving the research aim.
4. Analyse and interpret the data obtained through the research in line with the research plan and taking account of the similarities and differences compared to previous research and ensuring that the views of those that currently do not cycle are considered.
5. Reflect on the findings of the research considering their implication for both research and policy.
6. Present policy and future research recommendations relating to the impact of perceptions and attitudes on cycling behaviour based on the outcome of the analysis

Figure 1.1 shows how the aim and objectives of for this research fit together within the overall project structure.

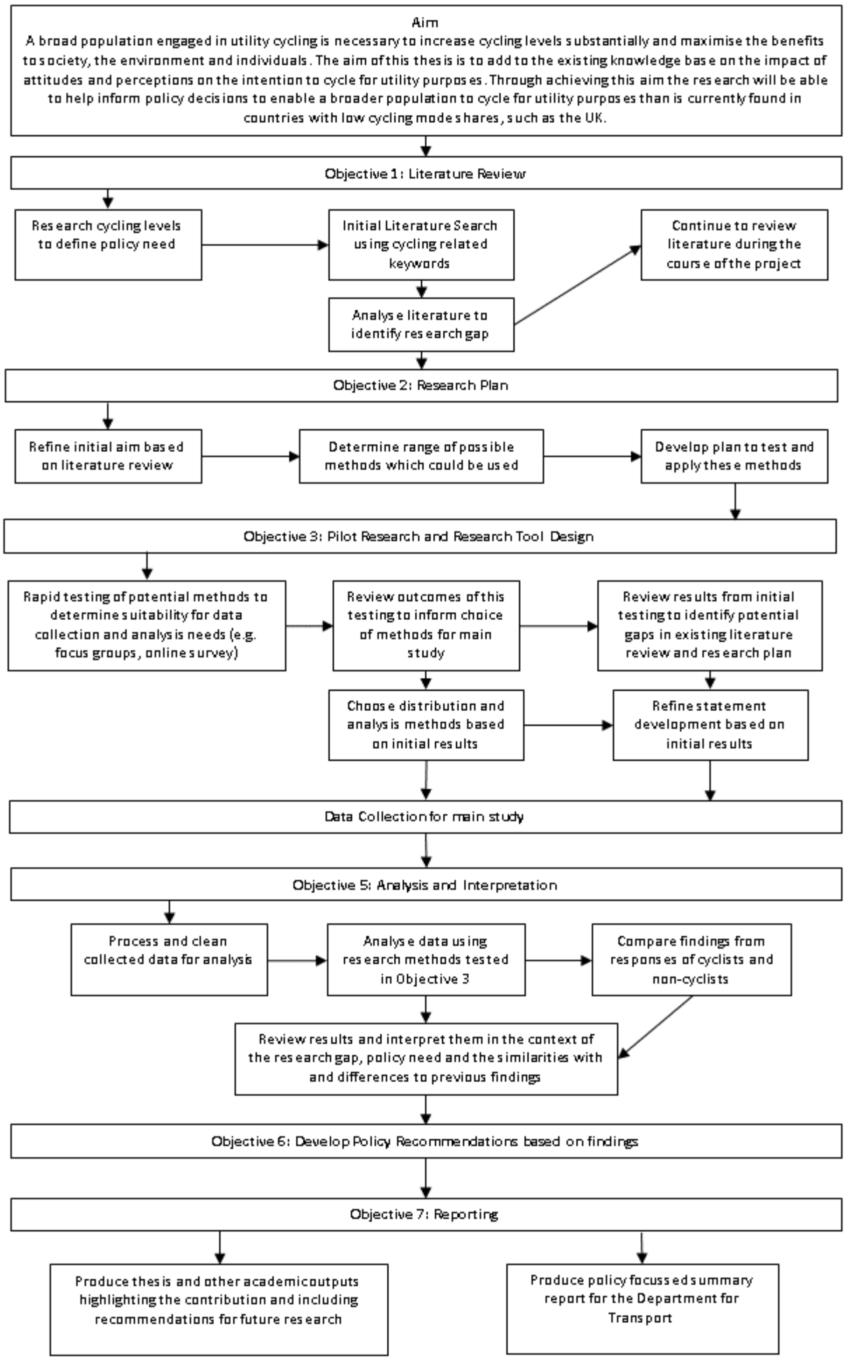


FIGURE 1.1: Flow chart showing research stages based on objectives

Chapter 2. Literature Review

2.1 Introduction to Literature Review

This literature review is split into the following sections: Sections 2.3, 2.4 and 2.5, address Objective 1 as set out in Section 1.6 The findings are summarised in Section 2.6 where the initial aims and objectives are re-focussed based on that summary.

Sections 2.7 and 2.8 address potential methods and frameworks which can be applied to the identified gap while Section 2.9 evaluates various a range of multivariate statistical techniques that may be applied to this research Section 2.10 summarises the research gap and lays out a research plan, further refining the aims and objectives initially set out in Section 1.6.

2.2 Literature search plan

This research project aims to improve our knowledge of the most important barriers and attractors to utility cycling. The literature review was conducted for two purposes:

1. To determine what research had been conducted into the attractors and barriers to utility cycling,
2. To investigate the research gap within this area and establish both the focus and range of methods to be considered for the research.

The literature search was conducted in three stages:

1. An initial literature search was conducted at the start of the project in October 2013. This literature review was conducted through searching relevant online databases (e.g. Google Scholar, Science Direct, Web of science, Transport Research Integrated Database (TRID)) for keywords relating to cycling.
2. The initial literature review was supplemented across the course of the project through subscription to relevant journals and smaller scale searches on specific topics which arose and identification of relevant citations within papers.

3. Later in the project, in June 2016, a follow-up search was conducted. The initial search terms were reused, alongside additional terms which had been identified through a meta-analysis of the bibliography to identify the keywords which were most frequently used within the papers which had been identified as relevant to the research in terms of the methods used and the relevance of the findings. This meta-analysis was then used to supplement the original search terms.

The follow-up search and the reporting of the literature have been conducted following the recommendations of Avni et al. (2015) which covers steps to define the scope, databases and search terms and reviewing the findings from a literature search. EndNote X7 for Windows was used to manage the bibliography throughout the project.

2.3 Determinants of Cycling

When looking at the current UK cycling levels in an historic and international context (as set out in Chapter 1) it becomes clear that there are many factors which have shaped the transport landscape we see today, such as government policy, public pressure for change and the implementation of infrastructure schemes such as those which aim to make cycling safer and more convenient while reducing the attractiveness of the car (Pooley, Horton et al., 2013) and those which make the car a more attractive mode (Bonham, Johnson and Burton, 2015). However, beyond this overview it is important to understand the impact of the various aspects of the policy environment, physical environment and social environment which influence people's actions alongside the importance of their individual capabilities, perceptions and attitudes.

Previous research suggests that a wide set of factors influence the intention of individuals to cycle, and that the importance of these factors in the decision-making process can vary significantly across demographic sub-groups, most notably defined by gender (Heinen, van Wee and Maat, 2010). In order to ensure a balanced growth in cycling, it is important to consider and understand the needs of different population groups when planning interventions, whether these be through hard measures (engineering interventions, such as the installation of cycle lanes) which generally target 'Hard Factors' or soft measures (such as promotions or cycle training) which may also tackle 'Soft Factors'.

Hard Factors are defined as measurable characteristics such as travel time, cost and effort which are governed by the physical environment (such as route surface quality and segregation from motor traffic). Soft Factors are defined as the personal and environmental factors governed by the wider context within which the decision to cycle is made (such as attitudes compatibility with working life and the support of family and friends) (Heinen, van Wee and Maat, 2010).

2.4 The Built and Natural Environment

There is a growing body of literature which recognises that safe cycling environments and supportive cultures are valued highly, particularly by female and older cyclists (Heesch, Sahlqvist and Garrard, 2012; Sahlqvist and Heesch, 2012; Aldred, Elliott et al., 2016). These messages are repeated in recent UK design guidance, such as the Sustrans Design Manual (Sustrans, 2014b) and London Cycling Design Standards (Transport for London, 2014). It has been suggested that in countries such as the Netherlands, Denmark and Germany, investment to develop cycling networks and cultures has made cycling safe, convenient and widely accessible, which in turn has made cycling a mainstream transport mode with high levels of cycling and less variation by age, gender and income level than in Great Britain (Pucher and Buehler, 2008).

Hard Factors are often associated with the perception of safety and journey quality and have been found to influence the level of cycling in an area; it has been suggested that Hard Factors seem to have a particular influence on those groups which cycle less within the UK (as described in Section 1.5).

Design guidance documents in the UK and abroad have attempted to group these Hard Factors under sub-categories which help to summarise the most important aspects. Initially based on the Dutch CROW (CROW, 2007) guidance, the common features also included within the London Cycle Design Standards (LCDS) are ‘coherence’, ‘directness’, ‘safety’, ‘comfort’, and ‘attractiveness’. An additional factor ‘adaptability’, which is included within the LCDS (Transport for London, 2014), is not relevant in this context as it is included to encourage designers to think about how cycling infrastructure can be changed to reflect changes, such as increased demand, rather than reflecting an issue that would affect the quality for a cyclist.

The influence of cycling infrastructure can also be divided into:

1. The importance of the presence of cycling infrastructure
2. The importance of a person's perceptions of that infrastructure and the associated perception of cycling safety (Ma and Dill, 2016).

Many studies in this area also examine elements of the physical environment which are not related directly to cycling infrastructure; for instance the built environment is studied in terms of the density of population and average travel distances to workplaces or other destinations (Handy, Xing and Buehler, 2010). The natural environment is also often considered with studies examining the impact of the weather (Dill and Carr, 2003) and topography (Majumdar and Mitra, 2015) on cycling levels. Again, as with cycling infrastructure, these physical elements can also relate to perceptions that these conditions can make it easy or difficult to cycle. Within the approach which looks directly at the influence of infrastructure there are three main methods for establishing the impact of infrastructure on cycling modal share and road choice at a population level.

1. **Comparative Studies:** A common method of establishing the importance of the presence of cycling infrastructure is to compare the length or density of cycle networks across multiple locations and determine whether this measure correlates with the level of cycling in these locations. However, there are limitations to this method as there are many other elements which may confound the situation and thus it is difficult to isolate the impact of the infrastructure.
2. **Reviews Best Practice:** The impact of confounding factors on studies which consider relative density leads some researchers to choose a second method which looks to acknowledge this issue and instead compares best practice, exploring common themes in successful areas.
3. **Longitudinal (or Pre/Post) Studies:** An alternative to both approaches is to study an individual route or area before and after the implementation of infrastructure improvements. This method also has limitations, as it is hard to account for issues such as displacement from other routes and the importance of neighbourhood networks.

Examples of each of these methods are reviewed below.

While the studies referred to above suggest that some elements of the built environment have a strong influence on mode choice (Schoner, Cao and Levinson, 2015) state that the methods used could underestimate the impact of personal characteristics. This study found that self-selection is an important factor. This study suggests that bike lanes act as magnets, encouraging those predisposed to cycle for attitudinal reasons to live in areas with good cycling infrastructure rather than encouraging non-cyclists to change their behaviour. This research used an ordered probit Heckman selection model to deal with the issue of cycling being a rare activity within the study area Minneapolis. As with Piatkowski and Marshall (2015) this study found that different factors were significant in participation and frequency models. The conclusion that bicycle lanes act as magnets rather that catalysts is based on bivariate correlation tests not shown within the paper which suggest that the attitudinal influence is stronger among those who have recently moved home. While this may suggest, as stated, that those attitudes precede location choice, this does not account for the issue that travel behaviour is more likely to change based upon a life event such as a change of residential or work location which may lead to a mismatch between previous underlying attitudes and practical options (Bohte, Maat and van Wee, 2009) meaning that those who have recently moved house may be more likely to considering their transport choices.

Buehler and Pucher (2011) investigated the association between the length of bicycle lanes and paths on one hand and the level bicycle commuting on the other across 90 of the 100 largest cities in the USA. Incorporating other data this study found that cities with safer cycling, lower car ownership, more students, less urban sprawl, and higher petrol prices had higher levels of cycle commuting. Consistent with (Dill and Carr, 2003) they also found that higher density of cycling infrastructure was associated with higher levels of cycling.

A study conducted in India identified similar factors to those found in European and American based studies described elsewhere within this review. Physical factors and safety related concerns were found to be important in influencing the choice to cycle (Majumdar and Mitra, 2015). This study also compared the views of experts and users' perceptions finding that route topography was perceived to be less important to users than experts. The authors highlight that this shows the importance of comparative studies such as this in situations where users are not involved in transport planning and note that the area the study was carried out is relatively flat limiting the users' consideration of steep hills.

When looking for examples of best practice it is common to look to Denmark and the Netherlands for the answer (Pucher and Buehler, 2008). However, it is also important to look at less developed cycling cultures such as cities in the USA and elsewhere in

Europe which have seen increases in cycle mode share in recent years. Several reviews have attempted to do this both in the academic arena and in industry to inform design guidelines. A non-peer reviewed report commissioned by Transport for London and conducted by Urban Movement and Phil Jones Associates visited case study areas across the UK, Scandinavia, Western Europe, New Zealand and the USA to examine best practice and identify common techniques and common conditions (Urban Movement & Phil Jones Associates and Transport for London, 2014). They divide the common techniques into 5 areas: 'Links', 'Junctions + Crossings', 'Network + Traffic Management', 'Interaction with Other Users' and 'Miscellaneous'. Based on these five areas, the document provides design guidance emphasising the importance of safe, dedicated space for cyclists within a network which is easy to navigate. The document also found that a common condition in cities which had been successful in promoting cycling was strong political leadership, which helped create a movement to promote cycling as part of an integrated approach to reducing car use. The report acknowledges the ongoing challenge and that the need to use simple and cheap methods, but insists that adequate provision of cycling infrastructure is a prerequisite for higher levels of cycling and that this requires the will to make significant changes to the streetscape. This has also been found in other documents on design guidance and best practice from countries with developed cycling cultures (Ligtermoet, 2006; CROW, 2007; Meggs et al., 2012; City of Copenhagen, 2014) and has more recently been adopted in cycling guidance in the UK (Sustrans, 2014b; Transport for London, 2014). While these themes around the physical infrastructure and governance emerge when comparing cities which have been successful in promoting cycling, a more critical approach is required to identify the effectiveness of policy actions. A meta-analysis entitled 'Infrastructure, programs, and policies to increase bicycling: An international review' (Pucher, Dill and Handy, 2010) warns of the potential for bias in the use of non-peer reviewed work on the effectiveness of interventions and comments on the lack of studies which have an adequate study design to allow the impact of individual interventions and policies (or a combination thereof) to be robustly measured. Despite these caveats, the authors also conclude that cycling interventions are most successful as a part of an integrated package. They also emphasise the importance of measures to discourage or restrict car use. As already noted (section 1.3) an earlier review for which Pucher was also the lead author concluded that the most important policy measure was the implementation of protected cycle routes on heavily trafficked roads and protection at junctions (Pucher and Buehler, 2008).

The issue of interventions to promote cycling has also been systematically reviewed by (Yang et al., 2010) who concluded that a combination of promotional activities and infrastructure interventions have the potential to increase cycling by modest amounts. The authors called for further controlled evaluative studies incorporating more precise measures and identified areas without an established cycling culture as a priority. A systematic review of the impact of the environment on cycling found that further research on the distributional impact of cycling infrastructure was required the socio-demographic distribution of the effects on physical activity from policies promoting the construction of cycle lanes.

Other studies have used 'pre-post' evaluation to examine the impact of the installation of specific pieces of new cycling infrastructure on cycling levels in that area. Some studies look just at the usage of that infrastructure while others attempt to establish the effect across a wider network. It can be difficult to account for trip displacement (Goodman, Sahlqvist and Ogilvie, 2014; Sustrans, 2017) and establish the true effect across the network (Goodman, Panter et al., 2013). If these issues can be addressed it is a very powerful tool, acting as a 'natural experiment' and allowing the changes in cycling level to be directly attributed to the presence of new infrastructure. A series of studies of the iConnect programme in the UK found that bridges which provided new, safe walking and cycling links between communities were effective in increasing cycling levels (Ogilvie, Bull, Powell et al., 2011; Ogilvie, Bull, Cooper et al., 2012; Goodman, Sahlqvist and Ogilvie, 2014) though in many cases the majority of usage was for leisure, rather than utility purposes (Goodman, Sahlqvist, Ogilvie and IConnect Consortium, 2013). However, by necessity, the focus of these studies is very narrow, limiting the scope for the inclusion of broader influences.

2.5 Beyond the Built Environment — Individual Level Factors

The above sections show how population level studies have been used to study the links between built environment factors and higher levels of cycling. Most studies which look to explore differences between individuals or groups regarding perceptions of the cycling environment tend to be more bounded in their geographical or investigative scope in order to produce clear results about their area of focus than is possible with other methods such as the reviews of best practice. Due to this, their ability to generalise findings regarding a range of factors across wider populations can be more limited. Most studies consider either a range of route specific changes across a potential user group (Hopkinson and Wardman, 1996; Steer

Davies Gleave and Transport for London, 2012) or a broader range of factors across a cohort with similar characteristics (Gatersleben and Appleton, 2007).

Qualitative work from projects such as Understanding Walking and Cycling (Pooley, Tight et al., 2011) and Cycling Cultures (Aldred, 2012) has produced evidence relating to the physical and physiological barriers to cycling. The importance of these factors, such as household routines, perception of risk, the risk of theft and the convenience of the car, appears to vary across the population.

2.5.1 *Journey distance*

Heinen, van Wee and Maat (2010) reviewed the literature regarding cycling to work and found that distance is almost always taken into account within cycling studies. This review found that distance is a significant variable with an increase in the commuting distance is associated with a lower cycling mode share.

van Wee, Rietveld and Meurs (2006) hypothesised that cyclists are disproportionately affected by distance as cycling requires more physical effort and is relatively slow compared to motorised modes. This is reflected in the sharp drop off in cycling mode shares for journeys longer than 5km which can be seen in datasets such as the National Travel Survey (Department for Transport, 2016c). While this effect is largely attributed the difficulties associated with cycling over longer distances, McCormack and Shiell (2011) found that studies of the impact of distance on physical activity do not adequately account for neighbourhood-self selection. Though the impact of distance should not be discounted this may mean that its effect may be over emphasised due to confounding factors, such as self-selection with those that already intend to cycle choosing locations closer to their workplace or other activities. This aligns with the work of Schoner, Cao and Levinson (2015) which argued that cycling infrastructure acts as a ‘magnet’ rather than a ‘catalyst’ but is countered by that of Næss (2009) and Ettema and Nieuwenhuis (2017) which find weak associations between attitudes and behaviour.

On balance the current research suggests that journey distance is an important factor in mode choice and particularly relevant for cycling. However, it may interact with attitudinal variables which are not apparent within population level data. As such it will be important within this research to compare the impact of journey distance to that of other factors.

2.5.2 *Attitudes and motivations*

The role of attitudes and motivations has been explored both through qualitative research and quantitative analysis of survey data. Perhaps unsurprisingly, positive attitudes towards cycling, the environment and the enjoyment of cycling are associated with higher levels of cycling while positive attitudes towards car use are negatively associated. Research on these issues is summarised in a review by Willis, Manaugh and El-Geneidy (2015).

There appears to be a difference in the importance of attitudes between high cycling and low cycling contexts. One issue in which this is particularly prevalent is the link between environmental values and cycling. Studies in the USA such as Handy, Xing and Buehler (2010) and Dill and Voros (2006) found that those who have greater concerns about the environment were more likely to be regular cyclists. In contrast, City of Copenhagen (2015) bicycle account consistently finds that environmental concerns are not an important motivator for cycling and Heinen, Maat and van Wee (2011) study in the Netherlands found that environmental concerns only become important in explaining the mode choice of those that choose to cycle long distances.

Positive attitudes towards cycling and the enjoyment of cycling are positively associated with higher levels of utility cycling in both high and low cycling contexts. A UK study based on an online survey found that those who had been cycling regularly for at least 6 months had more positive attitudes in comparison to those at other stages of change, with those that had not contemplated cycling having the least positive attitudes (Gatersleben and Appleton, 2007). The authors highlight the importance of targeting messages depending on the audience based on the stages of change model. Due to the poor attitudes towards cycling among those that have not considered cycling, it is recommended that some softer measures look to improve the image of cycling. They highlight that for many, especially women that don't cycle *"cycling is something that other people do"* with respondents reporting that others would find it strange if they cycled. For regular cyclists this study also found that, while they did have the most positive attitudes towards cycling, it was the direct benefits, particularly the flexibility of cycling, which seemed to be the most important in their decision to cycle.

The theme of direct benefits being key to regular cyclists is also repeated across both high and low cycling contexts. In addition to the work of Gatersleben and Appleton (2007) and Heinen's study in the Netherlands 2011 also found that most regular cyclists chose that mode because it was convenient in comparison to other modes. The importance of convenience has also been found in studies from Copenhagen and the USA (City of Copenhagen, 2015; Piatkowski and Marshall, 2015).

Utility cycling is also linked to the intention to decrease car travel and is negatively associated with positive attitudes towards car use and the enjoyment of driving (Bohte, Maat and van Wee, 2009; Heinen, 2011).

2.5.3 *Social Environment*

The construct of Subjective Norms is a core element within the Theory of Planned Behaviour (see Section 2.7.2). This refers to how you feel that those who are important to you would view you carrying out a particular behaviour. While, in some areas such as interventions to quit smoking (Armitage and Conner, 2001; De Vries et al., 1998), this effect can be very strong, a lot of transport research does not find this strong link (Willis, Manaugh and El-Geneidy, 2015). Heinen (2011) found that the subjective norm did not appear to influence behaviour for medium length or long journeys, but that there was a significant effect for short trips. Parental perceptions have large influence on children's behaviour (Willis, Manaugh and El-Geneidy, 2015).

The importance of Identity is an emerging element in cycling research which considers the social environment's influence on travel behaviour. While the descriptive and subjective norms link to how people feel they will be judged by others and what behaviour they think is normal identity may play a subtlety different but important role, especially for a minority activity such as cycling. The Understanding Walking and Cycling project also found respondents felt that cycling was seen as 'weird' (Pooley, Tight et al., 2011). More recently Lois, Moriano and Rondinella (2015) attempted to add Identity to the Theory of Planned Behaviour model to see if it improved the performance in explaining the 'Intention to Cycle' for commuting journeys. They found that those that could envisage themselves as cyclists, identified as a cyclist and felt they had things in common with cyclists were more likely to intend to cycle and found that this group was more predictive that the subjective norm. Heinen (2016) also found that identities were associated with intention to change transport behaviour. Both identifying as a cyclist, pedestrian and car driver which were all associated with intending to increase the usage of that mode (identifying as a driver was also negatively associated with looking to reduce car use) but also other feelings of identity, for instance, being a countryside lover was associated with an intention to increase cycling levels.

2.5.4 *Political environment*

The Staging Mobilities approach emphasises the importance of political leadership and decision making in creating the environment within which mode choice is determined, influencing mobility from the top down while the choices of individuals influence from the bottom up (Jensen, 2013). A paper modelling the determinants of the proportion of cycling journeys under 7.5km across cities in the Netherlands found that municipal policies impact on mode choice, with the key issue being the relative competitiveness of cycling compared to other modes. Other variables found to influence cycling levels were safety and satisfaction with the infrastructure. An additional issue which requires further analysis is that the proportion of immigrants in the population is related to the proportion of cycle journeys (Rietveld and Daniel, 2004).

2.5.5 *Gender and age*

As was demonstrated in the comparisons across different countries in sections 1.3 and 1.4, the gender and age distribution within the cycling population can be very different depending on the context. Generally female participation in cycling is lower but there is strong relationship between overall level and female participation, with the countries with the highest levels of cycling having equal participation or slightly higher female participation (Pucher and Buehler, 2008).

Regular cyclists, especially younger males, demonstrate higher levels of cycling confidence which is less affected by external environmental factors and unsupportive environments than less regular cyclists whose confidence more dependent on the context (Lam, 2017). Younger males tend to be less strongly affected by poor infrastructure, this is believed to partly account for the higher levels of cycling for this group in low cycling areas (see Chapter 1). Other factors such as journey purpose (for example females are more likely to make journeys with children which is a bigger barrier to cycling) also influence travel behaviour, this is a complex set of factors to be examined (Eyer and Ferreira, 2015).

While middle aged and younger adults generally have higher levels of mobility and cycling confidence, they are also more likely to commute long distances. This ‘conflict’ can be seen in their overrepresentation in low cycling environments where segregated cycling infrastructure is less common and their relative underrepresentation in some high cycling areas where cycling levels for longer commuting journeys are much lower than the mode share for those longer commuting journeys (Pucher and Buehler, 2008; Aldred and Crosweller, 2015).

2.5.6 *Fitness and mobility*

In surveys which ask about barriers to cycling, lack of fitness is often cited as a barrier by non-cyclists (Davies, Hartley and Transport Research Laboratory, 1999). In studies which compare the barriers to cycling using a longitudinal panel, this issue becomes less important as people continue to cycle (Davies, Hartley and Transport Research Laboratory, 1999). This could in part be due to their fitness improving, but is also linked to a pattern where those who start cycling report that many aspects of the cycling journey are not as bad as they had assumed as non-cyclists (Ma and Dill, 2016). Even small sections which require sharing the road with fast moving traffic can be a significant barrier to those who feel they are not physically fit enough to cycle safely in these situations. This means that fitness and mobility can be barriers for specific journeys, even if the majority of the journey is possible without sharing the road.

Local topography is another issue linked to fitness and mobility, with some non-cyclists reporting that their own area is too hilly (Horton, Rosen and Cox, 2007). While there is an association with cycling levels and topography (Parkin, Ryley and Jones, 2007) this is also linked to the difficulty non-cyclists have in imagining the routes they would use on a bike. Regular cyclists are more aware of routes that avoid difficult journey segments than occasional users meaning that alternative, flatter or safer routes may not be considered - increasing the barrier to cycling.

2.5.7 *Family and work*

Journey purpose is commonly found to be a determinant of mode choice (Horton, Rosen and Cox, 2007; Goodman, 2013). This is particularly pertinent to cycling as it can be seen to be restrictive for (i) commuting if office wear or carrying equipment is required, particularly in the absence of good showering facilities (Spotswood et al., 2015); (ii) shopping because of the heavy loads (Davies, Halliday et al., 1997) and (iii) escort trips as the confidence and ability of the children you are travelling with is an additional factor to consider (Aldred, 2015).

Children cycling independently is heavily influenced by parental perceptions (Bopp, Kaczynski and Besenyi, 2012) and influences parental mode choice as it reduces the need for trip chaining (Eyer and Ferreira, 2015). The need for trip chaining may encourage car use as people seek convenience when travelling for more than one purpose.

2.6 Research Summary, Refocusing Aims

The aim of this project (defined in Section 1.1) is to provide data and analysis that may help inform policy decisions to enable a broader population to cycle for utility purposes than is currently found in countries with low cycling mode shares, such as the UK.

Following the literature review covering the environmental determinants of cycling and individual level factors, gaps existing research can be established. Based on this review studies which combine the following features were not found;

- Individual level responses on cycling specific issues from a large sample of respondents.
- Include cyclists and non-cyclists.
- Ask respondents about their attitudes and perceptions.
- Address journeys beyond the commute.
- Combine this data with an objective measure of the cycling environment.

Due to the absence of studies which meet these specifications there is currently a gap within the research relating to the views of non-cyclists and the influence of their attitudes, perceptions, and their local cycling environment on their decision not to cycle for utility journeys.

Research which produced this combination of characteristics would allow a comparison of the relative importance to individuals, from across socio-demographic groups, of 'Hard' and 'Soft' Factors in relation to their intention to cycle. This would build on the current research base which has largely focused on the attitudes of existing cyclists and enable policy advice to be developed on which interventions may help encourage new cyclists and which may help improve the experience for existing cyclists and enable their continued participation.

This is particularly within the current context as broadening the pool of potential cyclists is vital to increase the cycling mode share beyond the levels which can be achieved through increasing cycling levels within the demographic groups which are currently more likely to cycle. Achieving this would also enable a more equitable distribution of the environmental, social and health benefits which cycling can provide.

Objective 2 (Section 1.6) which requires the development of a research plan to collect and analyse data to address the identified gap can now be refined to specify a theory-led, large scale, quantitative study which addresses these points. This study will allow the relative importance of 'Hard' and 'Soft' Factors to be explored through a theory-led approach which will increase the potential for comparability to smaller scale studies. Much of the previous research focuses mainly, or solely, on commuting journeys. As the primary aim of this study relates the need to enable a broad population to cycle for utility journeys the study should not focus on commuting journeys. Thus, the population of interest is all potential utility cyclists.

The sample should include fair representation of:

- Existing cyclists (including leisure or fitness cyclists) and non-cyclists (including those that would not necessarily see themselves as potential utility cyclists).
- Males and Females.
- Age groups.
- A range of socioeconomic groups.
- UK locations with a range of cycling infrastructure.

Achieving a large sample size which contains sufficient numbers of responses across these groups will allow for the factors which most influence those groups within the population which currently cycle less to be studied in comparison to existing cyclists, adding to the existing knowledge base and addressing the research gap.

2.7 Potential Analysis Frameworks

Now that the research area and populations of interest have been established, it is possible to review the analysis techniques which could be used to produce an analysis designed to answer these questions.

2.7.1 *Utility maximisation*

A common approach in transport research is to understand the choices people make regarding their mode choice and route choice through contingent valuation or discrete choice, as summarised in a review by Venkatachalam (2004). This approach originates within economics and looks to explain choices through assuming that individuals make choices to maximise their utility. Transport is a derived demand and thus the utility must be negative, meaning that it is assumed that individuals will choose the transport option which minimises their disutility (Caygill, 2014). The disutility is calculated by giving values to represent each of the determinants which are expected to affect the decision (Ortúzar and Willumsen, 2011), in practice a simplified equation is sought which includes only the variables which are found to be significant in predicting the choice. Commonly a monetary value is assigned to each variable to allow otherwise very different factors to be compared. This is achieved through studies of the 'value of time' or 'willingness to pay' or 'accept' changes to the service or route (Wardman, Chintakayala and Jong, 2016). In the context of cycling these studies look to establish values for elements such as perceived quality of infrastructure, safety, and journey ambiance (Department for Transport, 2014b).

This approach is very useful in predicting route or mode choice and is commonly used in transport planning (Wardman, Chintakayala and Jong, 2016), however it has several limitations which make it inappropriate for this research (Ryan and Spash, 2011). This approach usually assumes perfect information which in turn assumes that each individual is fully aware of the choices available to them and is able to compare each option to determine the 'best' option which maximises their utility (Akar and Clifton, 2009). This is a particular issue within this research which investigates the factors which are important to non-cyclists who are likely to have a lower level of knowledge of cycling than the mode they commonly use. It is also difficult to incorporate elements which are not specific to the choice in question, such as lifestyle factors which may influence their overall behaviour (Burbidge, 2008).

2.7.2 *Theory of Planned Behaviour*

The Theory of Planned Behaviour (TPB) is a model based in psychological theory which tries to explain the complexities of human behaviour. The basic theory assumes that the intention to perform a behaviour is a joint function of attitudes towards the behaviour, subjective norms and perceived behavioural control (Ajzen, 1991).

As identified by Lois, Moriano and Rondinella (2015) the Theory of Planned Behaviour has been used in many cycling studies as a basis from which to explore the factors influencing the intention to cycle. This has become more common as researchers look to understand the deeper psychological reasons that influence a person's intention to cycle which are not adequately explained by discrete choice models which focus on directly quantifiable variables such time and cost (Muñoz, Monzon and Lois, 2013).

While the Theory of Planned Behaviour is commonly applied to transport research in its standard form, some studies look to adapt this form to include other aspects which may influence intention and behaviour. An example of this approach is Lois, Moriano and Rondinella (2015) which tests the inclusion of social identity and finds that it improves the ability of their model to predict choice. A meta-analysis found that the application of Theory of Planned Behaviour typically accounted for between 27% and 39% of the variance in behaviour and that incorporating extra constructs may increase the predictive power, however it should be noted that additions to the core model can reduce the comparability across studies and may lead to unreliable conclusions if the additions are not built on a strong theoretical basis (Armitage and Conner, 2001).

Studies which use the Theory of Planned Behaviour commonly use the 'Stages of Change' scale as a measure of intention to carry out a behaviour (Lois, Moriano and Rondinella, 2015). The stages of change scale assesses an individual's readiness to adopt a new behaviour with the intention generally being seen to move through 6 stages 'Precontemplation', 'Contemplation', 'Determination', 'Action', Maintenance' and (where appropriate) 'Relapse', (Prochaska and Velicer, 1997). This model has been used previously in cycling research (Bekkum, Williams and Morris, 2011).

2.7.3 *Responses to the Theory of Planned Behaviour*

A common criticism of the Theory of Planned Behaviour is that it places too much emphasis on the individual's ability to control their decisions based on their preferences (Shove, 2010). Two alternative models which aim to overcome this weakness are now discussed.

One approach is to adapt the Theory of Planned Behaviour to account for the weaknesses in the base model by adopting in the socio-ecological approach. This model further acknowledges the impact of the physical environment on behaviour. Studies which use this approach in cycling research look to incorporate the physical environment through objective representations such as the presence of infrastructure, rainfall data or gradients (Madsen, 2013). While it can be difficult to integrate perceptions (Madsen, 2013) When these objective and subjective measures are combined within the same model, this allows us to see whether perceptions of the physical environment are linked to objective measures, and what their relative importance is. For example, this allows the investigation of the relative importance of the presence of cycling infrastructure and perceived safety.

There may be a link between the presence of infrastructure and cycling, but the respondents from areas with higher levels of infrastructure provision may not report higher levels of perceived safety. Through the application of a socio-ecological approach, the Hard and Soft Factors which this research looks to explore can be incorporated into a psychological framework. Another approach, arising from other criticisms that the behavioural approach does not place sufficient emphasis on the materials required for mass cycling (Shove, Pantzar and Watson, 2012) is to reject the underlying structure of the Theory of Planned Behaviour model and apply a totally different structure. One example of this, which has been applied in transport research, is Social Practice Theory (Guell et al., 2012; Spotswood et al., 2015). This approach conceptualises the action of interest as a practice rather than a behaviour, and emphasises the dynamic relationships between the materials required to carry out the practice, the skills required and the perceived image. One criticism of Social Practice Theory stems from its emphasis on dynamic relationships and the lack of a measurable 'behaviour' which is replaced by an unobservable 'practice'. Turner (1994) argues that if the practices are not observable they cannot be used to explain decisions in a meaningful way.

2.7.4 *Summary of analytical frameworks*

Utility maximisation was rejected as a framework the aim of this research is to explore the relative importance of Hard and Soft Factors which requires a broader range of variables which do not fit within the assumption that actions are based upon the rational decision to maximise utility. Social Practice Theory was rejected as the nature of the model does not seem to fit well with the use of quantitative methods and may be more applicable for qualitative research. Additionally, as there has been less research on cycling which uses the Social Practice Theory framework the potential for comparability to other studies is reduced. On the other hand, there are many studies using the Theory of Planned Behaviour. On recognition of the criticism of the core

Theory of Planned Behaviour the socio-ecological approach was adopted for this research as it was judged to best allow for the exploration of the relative importance of Hard and Soft Factors, set out as an objective in Section 2.6 through the inclusion of a measure of the respondents' perceptions of their local cycling environment and an objective measure of the cycling network in their area.

2.8 Quantifying Attitudes

An objective of this research involves exploring perceptions and attitudes relating to cycling and the cycling environment. Within quantitative methods there are two main approaches to measure attitudes and perceptions - direct methods and indirect methods.

Direct Methods: A common direct method is to present the respondent with a statement relating to each factor determine their level of agreement using a Likert scale (Bryman, 2016). This method is useful as it is simple for the respondent to understand and allows a distribution of responses for each factor to be analysed. However, the scaling method does not require respondents to compare the factors against each other which can reduce the researcher's ability to identify the most important issues. There are also concerns that Direct Methods suffer from a bias due to social desirability as the respondent knows their attitudes are being evaluated and may wish to provide answers that see as being socially desirable rather than their true evaluation (Couper, 2000).

Indirect methods: Commonly respondents are presented with a discrete choice between options. Within the discrete choice technique, a set of factors are chosen by the researcher which can be set at different levels. The respondent would then be presented with the options and asked to make a choice. Based on the set of choices made by the respondent when the values are changed it is possible to estimate the importance weight of each factor through the application of a logit model (Louviere and Islam, 2008). Another common way of assigning a value of importance is to include a contingent valuation question creating a Willingness to Pay (WTP) measure. This can be difficult in cycling research as each journey is perceived as free by the cyclist, but can be achieved through the inclusion of a separate cost such as a reward for cycling to work or a hypothetical toll (Hopkinson and Wardman, 1996). These methods are useful in order to integrate the perceptions of route users into a Cost Benefit Analysis and values derived using these techniques are included within the

Department for Transport's Transport Appraisal Guidance (WebTAG) for transport scheme appraisal to represent the value of cycle lanes and end of journey facilities to the average cyclist (Department for Transport, 2014b). Despite their advantages, indirect and WTP measures can suffer from issues when comparing different income groups and in determining whether outliers represent a high or low willingness to pay (Laird, Page and Shen, 2013). The latest WebTAG update attempts to address the equity issue by providing guidance on how to identify the net winners and losers by comparing how the impact is shared across income groups (Department for Transport, 2013a).

2.9 Exploring relationships between variables

Having established that quantitative methodologies were preferred in this research, it was necessary to evaluate the various the statistical techniques that might be applied to draw the inferences in this case. Most multivariate approaches consider a dependent variable which can be predicted or modelled based on analysis of a number of independent variables. In some cases, the independent variables can be used as indicators to form unobserved or latent variables which are themselves useful in understanding the dependent variable which may be referred to an output or target variable in some applications. As it has been established that the socio-ecological approach is to be used for this research methods which allow for the modelling of unobserved variables will be considered. In previous research regression methods have been used to explore the relationships between individual variables and the cycling intention/frequency, other researchers have used exploratory or theory led data reduction methods to group these individual variables with a framework (Heinen, van Wee and Maat, 2010; Willis, Manaugh and El-Geneidy, 2015). Data reduction techniques are used to enable a more parsimonious description of the data. This is useful as much attitudinal data consists of many variables which may be believed to represent a smaller number of underlying constructs (Bryman, 2016). Parsimony is a common aim of data analysis as it simplifies the data. This can be obtained when using techniques such as multiple linear regression where reducing the number of variables in the analysis increases the degrees of freedom, allowing for a more powerful analysis (Esposito Vinzi et al., 2010).

Additionally, when the underlying constructs can be related to existing behavioural theory this can allow for a more in depth discussion of the reasons for and implications of the relationships between constructs by relating the findings of the individual piece of research to other research using the same frameworks and/or the theoretical basis of the framework.

Following the appraisal of some of these methods, a suitable approach will be chosen.

2.9.1 *Regression*

Various regression techniques are commonly used in studies which aim to investigate the variables which affect the decision to cycle (Handy, Xing and Buehler, 2010; Heinen, 2011). These techniques allow researchers to investigate the relationship between dependent and independent variables. Linear regression has been commonly used in studies on determinants of cycling (Parkin, Ryley and Jones, 2007).

As well as linear regression, logistic regression has also been used in cycling studies (Piatkowski and Marshall, 2015) to show differences between binary choices, such as cyclist or non-cyclist. While this can help identify the key variables which are associated with this change, it does not allow the use of a stages of change approach, or other similar ordinal scales, which would allow a more in depth look at how people go from not cycling at all to being regular cyclists.

Some studies which use individual level survey data combine the questions within the survey into scales e.g. Handy, Xing and Buehler (2010). This can be done to derive more reliable average measurements (Reise, Waller and Comrey, 2000). However this does not represent the full modelling of latent variables (Hair, Mult et al., 2014).

2.9.2 *Factor Analysis and Principal Component Analysis*

Both factor analysis and principal component analysis are commonly used as data reduction techniques. They are often treated as interchangeable and will often provide similar results (Comrey, 1988). However, they are distinct methods and it is important to consider which method is appropriate for the research being undertaken. Principal component analysis is simply a data reduction technique. In contrast, when using factor analysis, the research is looking for underlying constructs which form a causal model. Because of this difference, factor analysis is more appropriate for model formulation but may provide incorrect results if applied when the assumptions cannot be met.

While these methods do allow the identification of the components or factors which explain the greatest variability within the sample, they do not allow for the researcher to combine indicator variables to incorporate theory-led unobserved variables, as this is required to fit the data within a theoretical framework further analysis will be required to meet the aims of this research.

Using a hypothesised model has several advantages as it allows consistent comparison across data sets and the ability to measure pre-specified variables of interest. However, there are disadvantages as it does not allow the best model for each dataset to be specified and underlying connections not included within the model may be missed. This could lead to incorrect conclusions being drawn as there may be variables that had no hypothesised link but actually make up an important factor that had not been considered.

Using factor analysis data provides a method of finding those unknown factors by simplifying complex data, it is widely used in the social sciences to explore correlation between variables and factors (Costello and Osborne, 2005; Kline, 2014).

2.9.3 *Importance-Satisfaction Analysis*

Importance-Satisfaction Analysis (ISA) (also referred to as Importance-Performance analysis) can be used to examine the impact of different aspects of a product, environment or service on the overall level of performance or satisfaction. This method involves asking two questions for each aspect using the same scale, one relating to the satisfaction and one relating to the importance. These values are then combined allowing the creation of an importance-satisfaction matrix which highlights aspects which have low satisfaction and high importance and therefore should be considered as a priority (Yahya, 2013). A main disadvantage of this technique is the greater survey length and repetition required for both aspects to be considered.

Additionally, it does not itself allow for the exploitation of the strength of the link between the variables and a dependent variable.

2.9.4 *Structural Equation Modelling*

Structural Equation Modelling (SEM) is a technique which looks to fit networks of constructs to data (Kaplan, 2008) and is commonly used to analyse the importance of unobserved or latent variables in relation to one or more outcome variables. Second generation techniques such as Covariance Based - Structural Equation Modelling (CB-SEM) or Partial Least Squares - Structural Equation

Modelling (PLS-SEM) are becoming more common in situations for which they are more appropriate than the first-generation techniques (such as Cluster Analysis for primarily exploratory research or Analysis of Variance (ANOVA) for confirmatory research) (Hair, Mult et al., 2014) as they allow the multi-stage paths from the measured variables to unmeasured latent variables (factors) to a target variable to be explored.

This technique is becoming more accepted in business and academic research (Ben-Akiva et al., 1999; Tenenhaus, 2008). It involves the specification of a path model which includes a structural model and a measurement model. The measurement model is a set of measured indicators which are brought together to form separate unobserved variables. The structural model represents the strength of the links between these constructs. Tests have been developed which help to show whether the indicators work together as a group and whether they are sufficiently different from other groups in the model (Fornell and Larcker, 1981). This can be used to explore a model pre-defined by theory or one developed by the researcher. It is advised that theory based models are used where possible (Hair, Mult et al., 2014) as this reduces the risk of links being assigned incorrect causality. Thus it has been suggested that SEM is also better suited to confirmatory research (Esposito Vinzi et al., 2010).

The correct application of CB-SEM also places requirements on the data which are limitations for this type of study. In particular, the data used should be normally distributed and the data set should be of sufficient size which may be hard to achieve (Hair, Mult et al., 2014).

In recent years CB-SEM has been used to explore the factors which influence the intention to cycle through the framework of the TPB (Passafaro et al., 2014; Lois, Moriano and Rondinella, 2015). While these studies have demonstrated that SEM can provide useful insights into the intention to cycle, in these cases the models have generally been applied at an aggregate level, with limited comparison of subgroups within the population of interest. Therefore, further work is required to investigate the relative importance of these factors varies between identifiable sub-groups. In this way, specific barriers to cycling for each group may be identified and policies developed to address them to hopefully encourage a more balanced growth in cycling.

PLS-SEM should be seen as a complementary, rather than competing, method to CB-SEM. There are some weaknesses to SEM which are strengths of PLS-SEM and vice-versa. PLS-SEM is better suited for exploratory research and does not place the same distributional demands on the data.

While caution has been raised against assuming PLS based approaches can deal with all data types (O'Loughlin and Coenders, 2004) and assuming Likert scales produce interval data (Jamieson, 2004) the soft modelling approach does allow well designed Likert scale data to be included (Hair, Mult et al., 2014). PLS-SEM has been found to be appropriate when assessing between group differences (Qureshi and Compeau, 2009). This method also allows the construction of an Importance-Satisfaction matrix which can be used to highlight areas which require investment (Hair, Mult et al., 2014).

There are two main estimation methods used within the measurement model when working with PLS-SEM. These are commonly defined as Mode A and Mode B. Mode A uses the correlation weights between each indicator and the construct; Mode B uses regression weights, which is the standard in ordinary least square analysis (Sarstedt, Hair et al., 2016). Regression weights not only take the correlation between each indicator and the construct into account, but also the correlations between the indicators. Traditionally mode A has been associated with 'reflective' measurement of constructs while mode B has been associated with the formative measurement approach (Rigdon, 2016). When specifying the measurement model and designing the questionnaire, it is important to determine whether the use of reflective or formative variables is appropriate. A reflective measurement approach uses similar statements which are considered to reflect the overall construct, removing one statement should not change the overall meaning of the construct and the causality is assumed to run from the construct to the indicator. A formative measurement approach uses separate statements which are together considered to represent all of the separate aspects which make up the construct. Formative indicators are not interchangeable and together form the construct they are intended to measure (Esposito Vinzi et al., 2010).

One limitation of PLS-SEM is the lack of an overall goodness of fit value such as that available in other regression techniques (Hair, Mult et al., 2014). However a pseudo goodness of fit measure can be calculated. This technique accounts for both the measurement and the structural models and is calculated as the geometric mean of the average communality and the average R^2 value. Due to the use of average communality it is more appropriate for models which use reflective rather than to formative indicators (Sanchez, 2013).

2.10 Methods; Summary and Conclusion

A method was needed which would help draw out information on the relative importance of a range of factors including a separate, objective measure of cycling infrastructure to inform priorities for investment. The advantages and disadvantages of the frameworks and methods which were considered within this review are summarised in Tables 2.1 and 2.2.

Based on this requirement, it was decided to adopt a direct survey methodology based on attitudinal statements. These attitudinal statements represent a key section of the questionnaire. They are listed in Table 4.2, 4.4 and 4.5; analysed in the attitudinal analysis chapter (see Chapter 5) and are used as indicators within the path modelling (Chapter 6). They were designed to capture the issues described within the Literature Review (above) and informed by developmental focus group work (Section 3.1). The full survey is included as an appendix (see Appendix A).

It may be difficult for participants (particularly less experienced or non-cyclists) to compare Hard and Soft Factors directly, or to make trade-offs between them. Because of this, direct methods (such as attitudinal statements) which will allow an evaluation of both elements without having to make comparisons were favoured.

An advantage of taking a theory-led approach whereby the model framework is based on theory, rather than specifying a model based on patterns within the data, is that specifying the direction of the relationships within the model is an important stage of the modelling process and should be based on established theory to avoid directional relationships being misinterpreted (Hair, Mult et al., 2014). Exploratory Factor Analysis and Principal Component Analysis were rejected as they were not as well suited to the decision to adopt a theory-led approach.

The ability to test more than one outcome variable is important as it is clear from the qualitative literature that satisfaction is not necessarily higher among those that cycle more, with some individuals cycling despite their low satisfaction with the infrastructure, possibly due to a lack of alternatives. This favours the application of CB-SEM or PLS-SEM.

As the response data is expected to be nonparametric and as the aim requires the data to be divided into many sub-groups, PLS-SEM was seen as the preferred method for this study as it is better suited to meet these requirements. The latter constraint is particularly significant in this case as one objective of the research involves analysing

Method	Advantages	Disadvantages
	Potential Analysis Frameworks	
Utility maximisation	Allows for variables affecting choice to be determined, Allows for incorporation into cost benefit analysis and transport modelling	Usually assumes perfect information and rational action, Difficult to incorporate wider factors such as lifestyle
Theory of Planned Behaviour	Provides framework for considering attitudes and broader factors and can be adapted, Can measure change on stages of change scale which may not be seen in behaviour	Adaptions can reduce comparability unless theory-based, Overemphasis on individual's choice without considering environmental factors
Socio-ecological approach	Combines environmental factors and theory of planned behaviour into single model	Can be difficult to combine perceptions and objective data
Social Practice Theory	Allows for consideration of environmental factors alongside attitudes, Allows for study of dynamic relationships between factors	Unobservable 'practice' difficult to incorporate into quantitative methods Turner
	Quantifying Attitudes	
Direct Methods	Simple for respondent to understand	Susceptible to social desirability bias
Indirect Methods	Allows for the relative importance of different factors to be assessed	Willingness to pay can lead to issues when comparing across income groups

TABLE 2.1: Summary of advantages and disadvantages of frameworks and methods considered within the literature review

Method	Advantages	Disadvantages
	Exploring Relations Between Variables	
Regression	Well-established and different methods can be applied depending on data	Focussed on single dependant variable, Does not represent modelling of latent variables
Exploratory Factor Analysis	Allows for underlying constructs to be explored	Not theory-led, can lead to misleading results when assumptions not met
Principle Component Analysis	Can explain variation within the sample	Data reduction technique, does not represent underlying constructs
Importance-Satisfaction Analysis	Can help prioritise action based on combination of importance and satisfaction.	Duplication of statements to measure both importance and satisfaction separately
CB-SEM	Allows for network of constructs to be modelled	Requires data to be normally distributed and larger datasets
PLS-SEM	Does not make same data requirements as CB-SEM, Appropriate for group comparison	Lack of true overall goodness of fit value

TABLE 2.2: Summary of advantages and disadvantages of methods for exploring relationships between variables

the data up in sub-groups, limiting the sample size. In addition while there are some existing studies which have used CB-SEM to investigate the attitudes of cyclists there are no previous cycling-specific studies which use PLS-SEM, as such the use of this method contributes to the knowledge base in testing it's suitability for this area of research.

This literature review has identified a research gap around the attitudes of both current and potential cyclists towards utility cycling in the UK which can be addressed by a large scale theory led study seeking to draw out information on the relative importance of a range of 'hard' and 'soft' factors to both groups and also including a separate, objective measure of cycling infrastructure. The use of a direct methodology in conjunction with PLS-SEM was identified as the most appropriate approach available for this study.

Chapter 3. Data Collection and Methods

As established in the updated aim and objectives (Section 2.6 and Section 2.10) the area of interest for this research is the relative importance of Hard and Soft Factors on the Intention to Cycle and how this varies across people at different levels of cycling and from different socio-demographic groups. These issues were discussed under the topic of determinants of cycling (Section 2.3).

In this chapter the data collection and analysis methods used within this thesis will be set out and explained. The theoretical basis of this research applies the socio-ecological approach based around the Theory of Planned Behaviour and will test the possibility of explicitly including the cycling environment alongside the broader perceptions of cycling usually included within the construct of attitudes towards the behaviour.

3.1 Pilot Focus Groups

3.1.1 *Setup*

In order to complement the findings of the literature review (Chapter 2), focus groups were arranged within Newcastle University to determine key themes which should be included within the questionnaire. There were three focus group events, with three participants in each group. They were held in late 2014.

Participants were recruited from staff and students at Newcastle University through convenience sampling (Bryman, 2016) and through advertising the opportunity to take part through university mailing lists and at sustainable transport events held on campus.

These focus groups formed an early stage of the research and were used to identify areas of interest which may not have arisen within the initial literature review to test the potential of qualitative methods for this research and to aid in the development of the pilot surveys. The approach taken was inspired by 'rapid prototyping' which has been established in software engineering and other areas (Tripp and Bichelmeyer, 1990) which aims to test ideas quickly and with limited cost to identify gaps and test suitability while limiting the time and financial risk.

Due to the constraints which arose from the position within the overall research and the difficulty of attracting non-cyclists to participate the sampling method, number and size of the groups does not meet the recommendations of Morgan, Krueger and King (1998). The makeup of the focus groups provides a further limitation, with only those connected to Newcastle University being present, which limits the breadth of experience represented within the groups. Despite these limitation these focus groups provided useful supplementary information to the literature review and assisted in the development of the pilot survey.

The questioning route was designed to explore both Hard and Soft Factors as defined in Section 2.3 Themes were identified by the researcher using the recommendations of Ryan and Bernard (2003), summarised by Bryman (2016) as looking for 'repetitions', 'indigenous typologies', 'metaphors and analogies', 'transitions', 'similarities and differences', 'linguistic connectors', 'missing data' and 'theory-related material'.

The group structure of the focus groups was as follows:

Group 1: A - White Male Regular Cyclist, B - White Male Regular Cyclist, C - White Male Occasional Cyclist
Group 2: A - Asian Male Regular Cyclist , B - White Female Regular Cyclist, C - White Female Occasional Cyclist
Group 3: A - White Male Regular Cyclist, B - White Male Regular Cyclist, C - White Male Regular Cyclist

All participants were post-graduate students or staff and aged between 25 and 50.

3.1.2 *Focus Group Results*

The questioning route covered:

1. Identity of a 'typical cyclist'.
2. Good and bad experiences of the existing cycling environment.
3. Factors which change day to day.
4. Improvements that would encourage others to cycle.

A number of themes became apparent which reinforce the issues identified in the Literature Review (Chapter 2). Four themes in particular have been highlighted.

1. Cyclists/People riding bikes.

2. Making Allowances.

3. Bike Storage.

4. Resilience.

These are summarised in turn.

Cyclists/People riding bikes: There was a clear line drawn between two different types of cycling. The first of these can be reduced to cyclists which fit the Middle-aged man in Lycra (MAMIL) Stereotype or 'Roadies' in reference to their use of road bikes (Daley and Rissel, 2011; Fitt, 2014). This type of cycling was characterised through the repetition of terms such as *"serious"*. For commuting trips 'serious' cyclists possessed the equipment required to travel long distances and confidence to cope with the *"hustle and bustle"* (group 1, respondent B, male) of cycling in the town centre.

This image was contrasted against a 'European' or 'casual' style of cycling. The European image was characterised by *"sit up and beg bikes"* (group 1, respondent B, male) with baskets rather than by road bikes. While this style of cycling was seen as more relaxed it was often discussed in terms of utility or 'everyday' journeys not just leisure. The contrast with 'serious' cycling. In general, European cycling was seen as an inclusive type of cycling enabled by the infrastructure available in cities such as Amsterdam. A key difference between this and the 'serious' cycling seen in the UK was that it was not part of the person's identity but just something that they did - *"you don't think of Amsterdam being full of cyclists, it's full of people riding bikes"* (group 1, respondent C, male). This contrast supports the literature which suggests that European style infrastructure is effective in enabling mass participation in cycling (Pucher and Buehler, 2008).

Making Allowances: A key theme, identified by one participant as *"making allowances"* was that in Newcastle cycling did not fit easily into your day and you had to compromise in order to allow you to cycle. This is similar to the findings of Understanding Walking and Cycling (Pooley, Tight et al., 2011).

Participants that cycled longer distances saw shower facilities as useful and they had adapted their daily routine around them *"I can just roll out of bed and sort myself out when I get into work. Where if those facilities weren't available cycling wouldn't be an option in the first place over long distances"* (group 1, respondent B, male). Others that lived closer to work felt that their cycling journey should not require them to use a shower *"I know other people shower at work but having cycled for 20 minutes shouldn't mean that I need to shower in communal showers, so again that's kind of out"* (group 2, respondent C, female). As such, cycling in traffic became a greater barrier, even for short distances, due to the physical effort required. This barrier was a particular issue when formal clothes were required for meetings with multiple respondents reporting that they would not cycle when they had a meeting - *"I always wear a yellow cycle jacket and I think no, I won't cycle if I've got a meeting because I've got a rucksack or whatever, you know, you've got a certain way of dressing"* (group 2, respondent B, female).

Central to the "making allowances" discussion was the issue of helmets. There is mixed evidence on the impact of compulsory helmet laws (Carroll et al., 2014; Curnow, 2005) but within the second focus group it was clear that having to wear helmets was driven by the safety concerns of friends and family and that once they felt they needed to wear a helmet the respondents were less inclined to cycle - *"I was first cycling without my helmet and I was told off by a number of people about how dangerous it is so I made allowances, I bought a helmet, and I'm definitely using my bike less now I have a helmet"* (group 2, respondent C, female).

Bike Storage: A concern for most participants was the risk of having a bike stolen. Participants reported keeping their bike in eyeshot when parked in town and felt that secure cycle parking was a vital part of being able to cycle to work. One respondent stated that they were happier bringing their bike to work following the construction of a secure bike shed and another described how the issue of bike storage at home impacted on their cycling to work *"It's really awkward to keep a bike in the hallway… so if I'm not using it I'll take it upstairs, if it's in the hallway I'm more likely to cycle but if it's upstairs I won't"* (group 2, respondent B, female).

Resilience: With the issues identified above it is perhaps unsurprising that those cyclists who cycled regularly had built up a level of resilience and knowledge as reflected in Cycling Cultures (Aldred, 2012). Resilience was commonly reported in the terms of dealing with conflicts with car drivers *"the worst thing for cyclists would be drivers and when someone passes you and they are shouting at you"* (group 2, respondent A, male). Within this discussion cars were separated from busses and Heavy Goods Vehicles in relating to a different type of risk. Cars were more associated with the risk of speed. It was taken for granted that cycling involved danger but must be accepted if you want to cycle in the current environment *"you just get used to it, you just take it"* (group 2, respondent A, male).

The analysis described above was considered in the development of the Pilot Survey (Section 3.3) and the Main Survey (Section 4.3). The use of the data in survey design is discussed below.

3.1.3 *Focus Group Discussion*

As discussed above, there were several limitations which limit the weight that can be given to the findings within the overall research. Nevertheless, several interesting topics arose from the focus group analysis which helped to inform the statement development for the surveys used within main study.

The limited population which was recruited through advertising the focus groups and the impact of this on the range of views expressed reinforced the need for a research method which would allow for the views of non-cyclists to be analysed within the main study.

3.2 Survey Design

It was determined that the use of attitudinal statements would be the most appropriate survey methodology as this approach is well suited to the research question and allows collection of data on a large scale while not requiring the participant to make trade-offs. The methodology allows simple statements to be presented to the participant, allowing them to think about each element individually. A statistical method can then be used to test the relative importance of each of these elements on the variable of interest.

Dependent and Independent Variables: In this case the independent or endogenous variables would be the questions relating to each element of the Hard Factors (environment and infrastructure) and Soft Factors (attitudes towards cycling, social norms and perceived behavioural control) found within the literature review or raised during the Focus Group Study (Section 4.1). The dependant or exogenous variable would be the measure of the level of cycling an individual does (Cycling Frequency) or a measure of Intention to Cycle (established in Section 3.2.2).

Closed-ended questions were used throughout; due to the plan to collect extensive data from a large number of respondents, this was deemed necessary to simplify data processing and increase the consistency of response across respondents. This was balanced by the use of open text questions (i.e. "other" boxes) to allow respondents to provide clarifying information and a comment box was included at the end of the survey which allowed respondents to specify any issues they felt were not covered within the survey. This allows a qualitative analysis of important issues and may inform the design of future surveys.

- Multiple choice questions were used for questions intended to determine the demographics of the survey respondents.
- Seven point Likert scale questions were used to determine attitudes.
- Eleven point scales (0-10) were used to determine overall levels of satisfaction The Likert scales were used to represent the strength of agreement or disagreement with statements designed to elicit opinions on (i) the cycling environment in the respondent's local area and (ii) how cycling does/would fit into their home and work lives.

These scales were chosen to provide a higher level of choice for the respondent and granularity in the response data than would be obtained with shorter scales such as a five point scale (Cohen, Manion and Morrison, 2011). This scale type can be seen in within the context of an individual's overall confidence that they could increase their level of physical activity within healthcare (NHS, 2009).

The order of the Likert scale questions was randomised to reduce bias from patterned responses or fatigue.

3.2.1 *Quantifying the Cycling Infrastructure*

In order to incorporate cycling infrastructure into the model used for this analysis a measure of the cycling infrastructure provision was required.

Many cycling studies focus on the commute (Heinen, 2011). This has many advantages as it is a journey which people make regularly. It therefore has a large impact on their travel behaviour and is generally made using the same mode and route meaning respondents have a higher level of knowledge about attributes such as the time taken. This focus may be too narrow and risks excluding the experiences of those who do not have a regular commute or do not work. Thus an approach which covered general travel was adopted to help understand the factors affecting behaviour across a broader population and experience than would be possible by focussing on the commute. In light of this it was decided that the best method to adopt for the quantification of the provision of cycling infrastructure would look to identify the length of cycle routes in the local area for each respondent as a representation of the quality of the cycling environment in which they would start or finish most of their journeys. This technique has been used in several studies (Handy, Xing and Buehler, 2010) and allows for an objective measure of the cycling environment which while limited in detail can be applied at scale without obtaining route details from respondents.

This method for quantifying the local cycling infrastructure requires a method of locating each respondent. Within data collection there was a balance between over-burdening the respondent, privacy and collecting information about their place of residence. Based on this balance the decision was made to ask respondents for their postal district (e.g. E17 or SW1). It was decided that this was the highest level of precision which respondents would reliably provide. Some respondents to online surveys are unwilling to give their full postcodes and, when dealing with populations such as cyclists which are relatively sparse, they can be combined with other variables such as ethnicity and age to make individuals identifiable.

Other geographical areas commonly used within analysis of this type such as lower super output areas (LSOA) would not be suitable for this approach as people do not know within which LSOA they live and thus they are commonly derived from lower level data such as postal codes.

By downloading the OpenStreetMap transport network and the postal district boundaries it is possible to work out the length of the cycleways in each postal district.

Postcode data does not provide an ideal geographical measurement as districts vary in size between urban and rural areas and are not directly linked to population levels. This variability meant that it was particularly important to determine the appropriate denominator when calculating the level of provision for each postal district. Due to the variability in the size of postal districts the total distance of cycling infrastructure in each districts was rejected as an option. Two options were shortlisted:

1. Length of cycleways / length of roads
2. Length of cycleways / area of postcode district

Each method would represent a different measure of provision.

Option 1, the comparison of cycleway length to road length, would show how much of the transport network has been designated a cycleway, and may represent a measure of how much has been done in the area to make the network safe for bikes. However, this approach may over-estimate the impact of cycleways in rural areas where there are still long distances to travel and there is not a dense network of cycleways. Option 2, the comparison of the length of cycleway to the area of the postcode, would represent the density of the cycleway network and this may better show the accessibility of the area by bike. A postcode that scores highly on this measure will have a lot of cycleways for the area meaning that it will favour dense networks which have been shown to be linked to higher levels of cycling. However, a potential drawback of this method is that it may simply act as a proxy for density which while, linked to levels of cycling with cycling levels generally higher in cities, is not what this measure is intended to achieve. This effect could be mitigated by comparing the output of a model which uses this approach to the outputs of a model which uses a measure of the density of roads (length of roads/length of cycleways). If the impact of the cycleways measure is significantly greater than the impact of the all roads measure then it would appear that the cycleways were having an effect beyond that of density. Both measures suffer from the lack of a measure of quality. The data is based on OpenStreetMap which is an open source mapping platform built on edits by users. In OpenStreetMap a route is classified as a cycleway if an editor has labelled the route a cycleway. While there is guidance to reduce the variability in the designation, the description of a cycleway includes a painted on-road cycle lane to a fully segregated cycle track. This lack of a measure of cycle lane quality would lead to the over valuing of painted on road cycle lanes which are less favoured by cyclists. CycleStreets provides an online service where fast, balanced and quiet routes can be found for journeys based on an origin and destination. This website uses factors within the OpenStreetMap data such as road speed to determine the level of 'quietness'.

The Propensity to Cycle tool (pct) (Lovelace et al., 2016) estimates where existing flows (using the 2011 census) or increased flows based on scenarios of different levels of increased cycling would go across the network and uses the CycleStreets classifications to develop fast and quiet networks. Using the density of routes which were classified both fast and quiet was considered as a measure of quality, however, as explained in the pct manual where no quieter route is available CycleStreets will classify the route as the 'quietest' available. This means that not all routes classified as quiet would be inviting for a cyclist and this would be particularly over value routes in rural areas where there is no alternative.

Given the relative strengths and weaknesses of each of the approaches, it was decided that the density of cycle routes was the most appropriate measure as it shows both the efforts made to improve the cycling environment and the accessibility by bike in the area.

3.2.2 *Quantifying Cycling Frequency and Intention to Cycle*

As described in the literature review chapter (section 2) there are many different ways in which cycling frequency is measured. The requirements for the measure used in this thesis are summarised below:

- Focus on utility journeys rather than leisure cycling.
- Applicable to, and understandable, by both cyclists and non-cyclists.
- Distinguish between non-cyclists who would consider cycling from and those that would not.
- Reflect travel behaviour.
- Based on an accepted scale.

Distance or Frequency: The requirements of this study mean that a scale based purely on frequency, distance or time spent cycling would not be suitable. Distance or time spent cycling would differentiate people based on the amount of cycling they did, but would risk over representing those that made long cycling journeys over people that made short but regular cycling journeys. Frequency would better represent this, but would not differentiate between those who made lots of journeys, only some of which were by bike, and those that made fewer journeys, but used a bike for most of them. Trip rates vary by age and gender and so, given the variation in cycling levels across age and gender, and the focus on replacing 'regular journeys' by car with other active travel within policy, it was decided that a measure which reflected the proportion of journeys made by bike would be most appropriate.

Stages of Change: A better reflection of proportion of journeys might be achieved through the use of the stages of change scale (Section 2.7.2) alongside the incorporation of levels which differentiated between non-cyclists that had not considered cycling on one hand and those that either had considered it or were making plans to make more journeys by bike on the other. The stages of change model is a way of monitoring progress in adapting and maintaining new behaviours and is used widely in healthcare to monitor people's progress on programmes such as addiction management. It is reviewed in some detail in Chapter 2. It may be a particularly useful framework for this thesis when considered in the light of research that has compared cyclists at different stages of change suggests that the reasons for choosing to cycle to work are not the same as the reasons for increasing the frequency of cycling to work (Prins et al., 2016).

As the chosen model is based around the Theory of Planned Behaviour it was also decided the Stages of Change model would be used to structure the target variable when measuring cycling participation. Across the stages of change process there are four main 'sub-populations' within the overall population that are of interest within this analysis:

1. Those that do not cycle and are not considering it (Precontemplation)
2. Those that do not cycle and are considering it (Contemplation/Determination)
3. Those that already cycle occasionally/have recently started (Determination/Action)
4. Those that already cycle regularly (Maintenance)

Two Levels of Cycling (Upper and Lower Band): To study these potential subgroups it is necessary to define a cut-off point based on the frequency of current cycling above which respondents may be classified as 'Upper Band Cyclists'. Within the literature there are various definitions used to classify cyclists, and regular (or frequent) cyclists. When defining 'cyclists' a commonly used definition is those that have cycled within the past year (Heinen, 2011) though some researchers and institutions classify those that have ever cycled as cyclists. In defining regular cycling there is also some disagreement in the literature. Several researchers classify those that have cycled in the past week as regular cyclists. On the other hand, others define regular cycling as those that have cycled in the past month. This definition fits alongside the nationally available data on cycling from the Active People Survey.

Due to the relatively low level of cycling in the UK and the availability of the Active People Survey data as a comparison it was decided that once a month would be the most appropriate top level splitting point with the cohort for data collection. This cut off point is used to structure the analysis into a dataset for Upper Band Cyclists (once per month or more) and one for Lower Band Cyclists (less than once per month).

These two datasets analysed separately within the path modelling analysis (See Chapter 6).

Three Levels of Cycling (Frequent Cyclists, Occasional Cyclists and Non-cyclist): Analysis of those that currently cycle less than once a month examines which constructs are linked with contemplating making journeys, or actually making occasional trips by bicycle. If differences are found between these groups, further information can be gained through comparisons with those that do not cycle at all and those that cycle at least once a week at either end of the scale. Within the attitudinal analysis the data is divided into three levels. There are:

1. Frequent cyclists (F) who reported cycling at least once a week
2. Occasional cyclists (O) who reported having cycled in the past year
3. Non-cyclists (N) who did not report cycling

These definitions were chosen for the analysis in Chapter 4 and 5 to help draw out the differences between these groups.

As the measure of cycling frequency included both leisure and utility cycling while the measure of the intention to cycle focusses only on utility cycling analysis of those that cycle at least once a month examined which constructs appear to influence an increase in frequency, from cycling 'occasionally for any purpose' to cycling 'regularly for utility purposes'.

3.2.3 *Demographic Questions*

Respondents were also asked questions intended to assess: Physical Activity; Socio-economic Group; Place of Residence; Cycling Behaviour; Age and Gender; Ethnicity; Children living at home; Mobility; Bicycle ownership; Car ownership; Travel Behaviour; Job type; Commute.

Details of the questions used are given in Chapter 4, where the results are also analysed.

3.3 Pilot Survey

The purpose of the pilot within the formative stage of the project was to develop both the questionnaire design and to choose an analysis method. As such the PLS-SEM method was compared against another method which would also allow the creation of an Importance-Satisfaction matrix.

For comparison the ISA method was chosen as a suitable method with which the research team had experience (Yahya, 2013) and that has been used previously to monitor the Taipei YouBike scheme (Yang, 2013). The chosen method directly asks for a level of importance and satisfaction with each factor. A gap analysis is performed on the data, highlighting the factors with the biggest gap between importance and satisfaction. This formed the basis of one version of the questionnaire.

The ISA method was compared with PLS-SEM. Within the PLS-SEM questionnaire agree-disagree scales would be used as a proxy for satisfaction within the PLS-SEM allowing topics to be raised more naturally in a way that should make sense to non-cyclists. This formed the basis of the second version of the questionnaire.

If similar patterns are seen in both surveys then this would suggest that these statements make a suitable proxy.

3.3.1 *Pilot Survey Launch*

A draft questionnaire was tested in a seminar of approximately 15 Academic Staff and PhD students from a Transport Operations Research Group at Newcastle University. Based on the feedback from this the draft was amended and launched as a Pilot Survey conducted in winter with cyclists at Newcastle University in November and December 2014.

Over the period of the launch N=99 responses were obtained to the online version. Additional responses (N=13) were obtained when paper versions of the survey was also distributed to staff and students from Newcastle University at an event on winter cycling. These respondents were allocated one of the two questionnaires alternately.

The main changes from the draft were:

1. Statements about an individual's specific current or potential cycling route were dropped to be replaced by more general statements about the local cycling environment as non-cyclists found them difficult to relate to.
2. The decision was taken to test two different methods in the Pilot Survey (see below). Respondents were directed randomly to one of the two questionnaires from a central website, the link to which was distributed by email to staff and students from Newcastle University and Northumbria University that had expressed an interest in cycling and sustainability.

3.3.2 *Pilot Survey Results*

The survey respondents were all staff or students from Newcastle University and Northumbria University who were interested in cycling strongly limiting the applicability of the findings to the research aim, however, the pilot study provided a useful method for testing the questionnaire design and potential distribution and analysis method.

Two versions of the Pilot Survey was designed and launched. The first version was intended to pilot ISA methodology while the other was intended to pilot PLS-SEM methodology.

Due to the small number of responses it was not considered useful to test the data against national statistics. However, even without these tests, it was obvious that, due to the nature of the mailing lists and event, almost all respondents were regular cyclists and from a similar cohort (university staff and students). While this similarity limits the ability of the pilot to explain preferences across different groups it does allow decisions to be made about the methods with fewer complications than would be possible with an equally sized sample from a broader cohort.

3.3.3 *Lessons Learned from the Pilot*

The main outcomes from the pilot survey related to the information gained about the suitability of the survey distribution and analysis methods. The decision on which analysis method to take forward was informed by exploring whether the results aligned with the qualitative evidence and existing literature alongside a visual comparison of the spread demonstrated between indicators across both methods. Supporting data such as relating to the survey completion such as average response time and drop-out rate were also considered.

Primary Analysis Methods: The decision was taken to focus on PLS-SEM as the primary analysis method (Section 3.8) as the pilot survey results suggested that this would both help reduce the questionnaire length required and better represent the importance of potential factors.

The Impact of Summer and Winter on Responses: Results suggested that the gritting of cycle paths in winter weather was associated with satisfaction with the local cycling environment. It was felt that this highlighted the potential importance of temporal differences across seasons, with respondents potentially being more aware of the issues which they had experienced most recently. Thus, to reduce the influence of timing on the results, it was decided that the survey would be delivered in two waves. One wave representing autumn/winter and a second wave representing spring/summer. Weather data and automatic cycle tracker data were consulted to determine which dates would be suitable for data collection alongside other restrictions on timings, such as school holidays which were to be avoided because of the impact of different schedules and traffic levels during school holidays on behaviour and perceptions.

The first wave was collected between 08/09/2015 and 28/09/2015 and the second wave was collected between 11/02/2016 and 23/02/2016.

Accessing Non-cyclists: It was obvious from the responses that the distribution methods used were only effective in targeting active cyclists. This informed the choice of distribution method used within the main study, it was decided to use an On-line Access Panel (Section 4.2.4) which allows for non-cyclists to be reached. A potential limitation within this study which arose from the difficulty in obtaining responses from non-cyclists for the pilot survey is that this limited the level to which the statements used within the main study were tested within non-cyclists potentially leading to statements which were confusing to non-cyclists not being addressed at this stage.

3.4 Building and Testing the Model

The structural model represents the links between constructs. The hypothesised structural model was developed first, based on the socio-ecological model. The aim of the path model is to help provide information on the importance of the link between each construct and the Intention to Cycle. The hypothesised structural equation model was constructed based upon:

1. The categories within the Dutch CROW design guidance (CROW, 2007) and an objective measure of the cycling environment for Hard Factors.
2. Attitudes, Perceived Convenience, Subjective Norms, and Perceived Behavioural Control for Soft Factors.

Following a refinement process the model was tested using the validity tests described in Table 3.1 and described in detail in Section 3.9 to evaluate the measurement and structural models. An iteration process was used to organise the workflow for model development, providing a consistent approach and helped maintain a connection to the original hypothesised constructs. This process is summarised in Figure 3.1

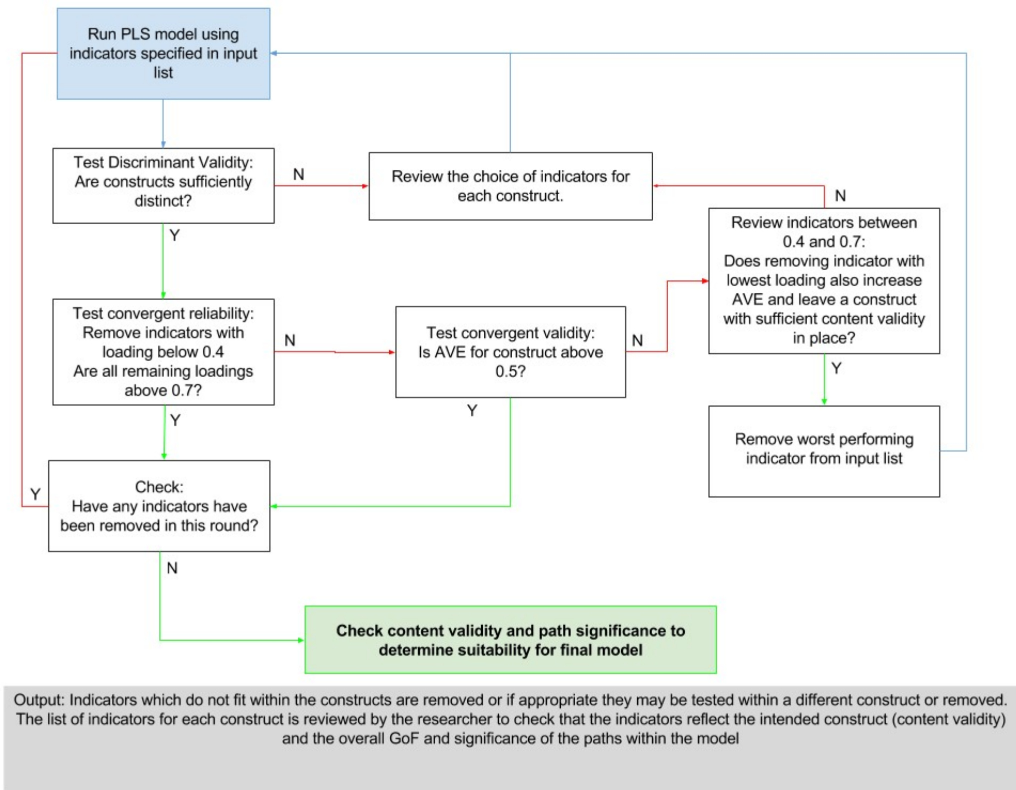


FIGURE 3.1: Summary of the Iteration Process used to Develop the Final Model

3.5 Statistical Software

The statistical analysis was conducted using R with RStudio used as an integrated development environment. Both programmes and the packages used within R were kept up to date across the course of the project with R 3.4.0 and RStudio Version 1.0.143 the most recent versions used.

3.6 Quality Checks

Descriptive statistics were used to summarise the data and to provide a basic understanding from which decisions about data processing and further analysis can be made. There were four areas of focus at this stage:

- Data quality
- Representativeness
- Normality
- Response patterns

There were also a number of validity tests which were applied to the PLS-SEM models (Chapter 6). These are described in Section 3.9.

3.6.1 *Data Quality*

There may be data quality issues, such as straight-lining with the Likert-scale questions, which could require responses to be removed (Nancarrow and Tapp, 2014). To help reduce these issues at the data collection stage, any respondent that took less than 6 minutes to complete the survey was automatically rejected. The minimum time was set at 6 minutes after reviewing cases of poor quality data from the soft launch.

The online survey tool (Survey Gizmo) which was used assigns every respondent a 'dirty data' score from 0 to 100, where 100 is the poorest quality data. This tool allows the user to specify which issues should be included when determining the score. As only 'straight-lining/patterned responses' was appropriate for this survey, this issue was selected and given the maximum weight (10). The tool indicated that the majority of responses showed no suspicious answer patterns. Responses that showed any suspicious response, indicated by any score of 1 or more, were rejected. Through this process 10% of the responses were removed. The order in which the Likert scale questions were presented was randomised to reduce bias, this means that the order in which any individual respondent was shown the questions is not known. Because of this, it was determined that the data quality scores allocated at the time of completion by the survey software would be used as post-hoc analysis would not be able to detect patterned responses (Survey Gizmo, 2015).

A further check was made to insure that the data for analysis was provided by genuine UK respondents. Using the Internet Protocol (IP) address of the respondents, only responses recorded as originating in the United Kingdom were retained. The postcode data provided by the respondent was then matched to the self-reported urban/rural description of the local area and the region in which they lived and cases where there appeared to be mismatches were also removed.

Following these data quality checks 88% of the data was retained for analysis.

3.6.2 *Shapiro-Wilks Normality Test*

The attitudinal statements were tested to see whether they could be assumed to fit within the normal distribution. Within frequentist statistics there are two approaches; parametric and nonparametric. Many researchers see parametric methods as preferable since they have greater statistical power, allowing small differences between groups to be revealed with more confidence (Bryman, 2016). However, the application of these methods requires more assumptions regarding the nature of the of the data to be made. Parametric statistics require assumptions which non-parametric methods do not; (i) that the data are based on interval level of measurement or above and (ii) that they are well described by the normal distribution. Non-parametric methods provide a more appropriate option if these assumptions cannot be met. If parametric methods are used when the required assumptions are not met this can lead to Type 1 error which can result in differences being accepted which are not really present within the data.

Within the range of non-parametric methods there is still a range of assumptions which, depending on the specific test, may need to be met regarding skewness or kurtosis within the data.

Thus Shapiro-Wilks normality tests were applied to the data. Where $p < 0.05$ the null hypothesis (that the data was normal) was rejected.

3.6.3 *Representativeness*

In addition to the precautions taken as described in section 3.6.1, the data was compared to nationally available data regarding age and gender distribution within the population, this analysis is reported within Section 4.4.

3.7 Hypothesis Testing

Non-parametric tests were applied when dealing with responses to the attitudinal statements. In addition, non-parametric tests were preferred when data were not ratio or interval level.

3.7.1 *Mann-Whitney U Test*

In cases where averages are to be compared for nominal data with two levels the Mann-Whitney U test was used. The Mann-Whitney U test is a nonparametric test similar to the t-test. While it does not make the assumption of a normal distribution, the assumption that the distribution of both samples is the same is required. The null hypothesis for this test is that it is equally likely that a randomly selected value from one sample will be less than or greater than a randomly selected value from a second sample (Sheskin, 2003).

Where $p < 0.05$ the null hypothesis was rejected.

3.7.2 *Kruskal-Wallis Test*

In cases where averages are to be compared for nominal data with more than two levels the Kruskal-Wallis test was used. This is an extension of the Mann-Whitney U test and thus does not assume normal distribution but does assume that the samples originate from the same distribution. The parametric equivalent of this test is analysis of variance ANOVA. As with ANOVA, this test is used to test the null hypothesis that none of the samples stochastically dominates any of the others, but does not reveal which samples are significantly different from each other (Sheskin, 2003).

Where $p < 0.05$ the null hypothesis was rejected.

3.7.3 *Conover-Iman Test*

If the result of a Kruskal-Wallis test was significant, and the null hypothesis can be rejected, the Conover-Iman test (or Conover test) was used to determine where the difference lies. The Conover-Iman test has been chosen over the more widely known Dunn's test due to its greater statistical strength allowing for smaller differences between groups to be detected while not requiring the assumptions of parametric tests (Conover and Iman, 1979).

Where $p < 0.05$ the null hypothesis was rejected.

3.7.4 *Chi-Squared Test*

Pearson's chi-squared test was used on tables of observed and expected frequencies to determine whether sample distributions (for example age and gender) matched the expected population. The null hypothesis (that the observed and expected frequencies were similar and thus that the sample was a good representation of the population) was rejected at $p < 0.05$.

3.7.5 *Spearman's Rank Correlation Test*

The Spearman's rank correlation coefficient ρ was calculated used to explore the strength of links between two sets of data. Values of rho were reported and discussed individually.

3.8 Partial Least Squares Structural Equation Modelling (PLS-SEM)

Based on the review of potential multivariate tools in Section 2.9 it was decided to adopt PLS-SEM as the main tool to extract meaning from the data.

3.8.1 *Partial Least Squares - Multigroup Analysis (PLS-MGA)*

The data were divided into groups by age, gender and cycling frequency to compare the path models. In order to test for significant differences between groups a Partial Least Squares - Multigroup Analysis (PLS-MGA) was conducted. For two group comparisons the permutations method were used this (Henseler, 2012).

While it is possible to achieve unified model through this approach there are different opinions on how the principle of measurement invariance should be treated within the literature (Sarstedt, Henseler and Ringle, 2011; Henseler, 2012; Henseler, Hubona and Ray, 2016). To conform with the principles of measurement invariance the measurement question should be conceptually similar across each sub-group and it is commonly argued that if this is not the case that the comparison cannot be made meaningfully. However, others argue that there will be cases where the principle of measurement invariance is illogical and that any comparisons made between groups should be made but treated with appropriate caution. The sub-groups will be tested for measurement invariance before comparisons are made.

There are several possible approaches for the comparison of groups as summarised by Sarstedt, Henseler and Ringle (2011). As the Likert scale responses are expected to be nonparametric and the groups may not be of equal size a confidence interval approach will be used. In order to perform this test the model must be run for each group in turn and bootstrapping is then performed to establish confidence intervals for each group. If the confidence intervals for two groups do not cross there can be said to be a significant difference between groups (Henseler, 2012).

This analysis was conducted within the plspm package in R (Sanchez, 2013).

3.8.2 *Response Based Unit Segmentation (REBUS)*

A supplementary stage of analysis was carried out to identify groups of respondents beyond the age and gender groupings used within the PLS-SEM sub-group analysis based on patterns within the data. This was achieved through the application of Response Based Unit Segmentation (REBUS) analysis which groups respondents with similar responses into segments (Stahlbock, Crone and Lessmann, 2010). By performing descriptive statistics demographic similarities within each segment can be found to help understand the nature of each class. Unlike cluster analysis methods which can also be applied to this type of data the REBUS algorithm considers the path coefficients within the segmentation allowing a more meaningful comparison of the structural model across each group.

The number of classes is determined through the interpretation of a dendogram created using the Ward method for Hierarchical Clustering.

3.9 Validity Tests

There are several checks which must be performed to test the performance of the measurement model. These are discussed below and summarised in Table 3.1.

Internal Consistency Reliability: A measure of the correlation between the indicators and this is typically the first criterion to be evaluated when determining the fit of a model. Across methods such as factor analysis and SEM the traditional criterion for internal consistency is Cronbach's alpha.

However, there are issues with Cronbach's Alpha when applied to PLS-SEM. One issue is that Cronbach's alpha assumes all indicators are equally reliable, to meet this assumption all indicators would have to have equal outer loadings on their construct. This contradicts the prioritisation of indicators according to their individual reliability (i.e. the level of their outer loading) in PLS-SEM (Hair, Mult et al., 2014).

The second issue is that Cronbach's alpha is sensitive to the number of items in the scale, generally underestimating the level of internal consistency reliability, especially for constructs with a low number of indicators (Hair, Mult et al., 2014). As such, composite reliability, an alternative measure, is generally felt to be more appropriate as it takes into account the outer loadings of each indicator.

Dillon-Goldstein's rho (ρ) (Esposito Vinzi et al., 2010; Sanchez, 2013) is the most appropriate measure for Internal Consistency Reliability when constructs are represented by low numbers of indicators and is used here.

As with Cronbach's alpha, the scale for Dillon-Goldstein's rho runs from 0 to 1 and the same cut off points are used to judge an acceptable level of reliability. Values between 0.7 and 0.9 are seen as satisfactory (Nunnally and Bernstein, 1994). In exploratory research these values may not be achieved, however, values over 0.95 and below 0.6 are not acceptable as they indicate a very high or very low level of correlation between the indicators which would indicate a poor measurement of the intended construct.

Convergent validity: As described by Hair, Mult et al. (2014) convergent validity is the "extent to which a measure correlates positively with alternative measures of the same construct". Within a reflective model each indicate is treated as an alternative measure of the same construct. As such it would be expected that these indicators should share a high proportion of variance.

When testing for convergent validity the researcher examines the Average Variance Explained (AVE) for each construct which represents the amount of variance extracted for the construct relative to the amount of variance due to measurement error (Fornell and Larcker, 1981).

The common test for this issue is that the AVE should be greater than 0.5, which indicates that the shared variance between the indicator and the construct is greater than the variance from measurement error (Hair, Mult et al., 2014).

Convergent reliability: The outer loadings of each individual indicator should also be examined in order to ensure that they are sufficiently similar to the other indicators used for the same construct. Ideally all indicator loadings should be >0.708 (often 0.7 is treated as acceptable), as this implies that the construct accounts for over 50% of the indicator's variance. However, particularly in the social sciences, newly developed scales will not achieve this (Hulland, 1999). In these cases, the researcher's judgement must be used in order to balance the benefits of including the indicator against improving the convergent validity by removing it. Reasons why the indicator maybe retained include content validity (Hair, Mult et al., 2014) and the improved reliability of PLS-SEM when constructs are represented by 3 or more variables (Sarstedt, Hair et al., 2016).

Generally, an outer loading of 0.4 is seen as the minimum acceptable outer loading (Hair, Sarstedt et al., 2011) below which the indicator should always be removed. Indicators of between 0.4 and 0.708 suggest an indicator should be considered for removal if this removal increases the composite reliability above the commonly used threshold of 0.5 for the AVE, a measure of convergent reliability above the threshold of 0.5 (Hair, Mult et al., 2014).

Discriminant validity: Testing for discriminant validity ensures that each construct is sufficiently distinct from each other construct included within the model. This requirement is necessary as it helps to determine whether each construct represents a subject not covered by the other constructs included within the model. In this study the more conservative of the two common approaches has been adopted.

This choice was made to ensure that discriminant validity was not mistakenly assumed to be present when two constructs were actually measuring the same overall phenomenon. In particular this was concerned a possibility with the perception of infrastructure as the divisions between the concepts in this area are less well established than those between the psychological constructs.

As such the Fornell-Larcker criterion approach was adopted (Fornell and Larcker, 1981). This test ensures that the AVE of each construct exceeds the squared correlation with any other construct. If this criterion is met then it implies that the construct shares more variance with its indicators than with any other construct included within the model.

Content validity: Unlike the other measures described here there is no scale used to measure content validity, instead a subjective judgement must be made by the researcher as to whether the indicators used adequately represent the construct.

This issue must be considered both in the data collection stage and also as the model is refined. Initially the researcher should be confident that the full breadth of the construct is adequately captured, for instance avoiding the use of redundant indicators (Hair, Mult et al., 2014). As the model is refined indicators may be removed from the construct based on other performance measures. It is though necessary to ensure that the construct is still adequately covered by the remaining indicators.

Goodness of Fit (GoF): As there is no overall goodness of fit measure for PLS-SEM the average of R^2 values in the model and average communality are used. This approach is applicable to reflective indicators. As with other goodness of fit measures, higher values indicate a better fit. Values over 0.7 are considered 'good' but often lower values are accepted in social science fields (Hair, Mult et al., 2014).

Pathway Significance: Once a model is developed which meets the other requirements set out in this section it is necessary to determine whether the hypothesised links within the model are statistically significant. Generally links which are not found to be significant should be removed, though they may be retained if they are deemed necessary for the content validity of the model based on the theoretical basis (Sanchez, 2013; Hair, Mult et al., 2014).

Within this study the path significance was tested using bootstrap analysis. This step is a form of validating the model by creating N samples of the same size of the original dataset through sampling with replacement. The model is then rerun for each sample creating an estimate of the precision of the parameter estimates generated for the original sample. The minimum recommended number of bootstraps (5000) (Sanchez, 2013) was used.

Testing of refined model	
Convergent Reliability	Indicator loadings should be >0.7 and should exceed 0.4 as a minimum.
Internal Consistency Reliability	Ideally Composite Reliability >0.7 but 0.6 acceptable in exploratory research. Cronbach's alpha can also be used as a conservative measure.
Convergent Validity	Average Variance Explained should be >0.5 for each construct.
Discriminant Validity	Fornell-Larcker criterion: Square root of the AVE for each construct should be greater than its greatest cross-loading.
Content Validity	The indicators which are included in the model should reflect the fullness of the construct they are intended to represent.
Goodness of Fit	Values of >0.7 desirable but lower values (>0.3) acceptable in behaviour research.
Path Significance	Tested through bootstrap analysis. Links between statements should be significant to 95%.

TABLE 3.1: Summary of Validity Tests applied to test the performance of the refined model

Chapter 4. Respondent Characteristics

4.1 Introduction to Respondent Characteristics

This chapter details the process of development of the main survey and data collection before presenting an initial analysis of the characteristics of the data, both at an aggregate level, and also for each of the subsamples which were used within the data collection in order to:

1. Determine whether there are differences in the sample which support or contradict previous findings on the relative importance of Hard and Soft Factors / perceptions, social environment and infrastructure.
2. Help explain the differences between cycling levels across social groups in the UK.
3. Reveal potential insights to inform policy which looks to encourage a more balanced growth in cycling.

Thus, this section allows the data to be understood at an overall level and, where relevant, comparisons to nationally available data have been made in order to determine whether the data is representative of the intended population.

A top level comparison on the data collected in each wave is also presented to test the suitability of this data to be treated as a single dataset. Also, the distributions within the data were tested to inform which approach would be suitable when analysing differences between groups within the data using methods introduced in Section 3.7 and 3.8. The nature of the dataset is analysed to test whether parametric or nonparametric methods would be more appropriate.

A more detailed analysis is presented using the selected methods. The data is split by self-reported demographic characteristics to determine whether there are significant differences between these groups. Comparisons by age group, gender and cycling frequency are presented and discussed for most of the attitudinal statements as these are the variables which have been found to influence perceptions in previous studies (Heinen, Maat and van Wee, 2011; Paige Willis, Manaugh and El-Geneidy, 2013; Aldred, Elliott et al., 2016).

The chapter concludes with a summary and discussion of the descriptive analysis described above. This summary is used to highlight findings from the descriptive analysis described in this chapter and also to discuss the implications from this analysis for the next stage relating to descriptive analysis of the attitudinal statements (Chapter 5) and path modelling (Chapter 6).

4.2 The Main Survey

The main online survey (See Appendix A for full survey) was designed to collect data on the cyclists' and non-cyclists' perceptions of the cycling environment and their perceptions of cycling.

4.2.1 *Attitudinal Statements*

The survey was built around a series of attitudinal statements against which respondents were asked to rate their agreement. These were treated as the dependent (indicator) variables in the subsequent analysis. The statements were derived from the findings of literature review (Chapter 2) and adapted following the Pilot Studies (Section 3.1 and 3.2)

The statements are listed in Table 4.2. Statements 1-25 are designed to capture views on attitudes towards cycling and cyclists while statements 26-47 focus on the respondents' perceptions of the local cycling environment. These statements were asked to all respondents. This includes statements 24 and 25 the 2 additional statements added to the second wave of the survey. These were designed to add to the subjective norm construct which showed a very low path coefficient within an initial model based on the first wave.

Table 4.4 also shows statements W1 to W6 which relate to the workplace, these statements were asked only to those who were in employment and who had a fixed place of work while Table 4.5 shows statements C1 to C4 which relate to the car use, these statements were asked only to those who reported driving within the past year.

4.2.2 *Statement Development*

Initial statements were developed through a combination of adapting those statements found in previous research such as Heinen, van Wee and Maat (2010) and

Handy, Xing and Buehler (2010), to cover other topics of importance found within the literature review and through the pilot focus groups (see Section 3.1). These statements were then refined through consultation testing within the pilot surveys (see Section 3.3) and in consultation with the DfT to ensure that they were clear and covered the topics of interest within this research.

Within the framework chosen for this research the statements for the 'Soft Factors' were developed in line with the Theory of Planned Behaviour (Ajzen, 1991) and those relating to 'Hard Factors' were designed to cover the breadth of issues within the CROW guidance (CROW, 2007).

Throughout the statement design and development process the recommendations of (Bryman, 2016) were considered. Bryman sets out the principles of statement design which, if followed, can ensure that the meaning of the statement is clear to the respondent and the response can be clearly interpreted by the researcher. These recommendations include avoiding ambiguous or technical terms, long questions and, importantly, avoiding leading questions.

One of the challenges within this project was designing statements that would be applicable to, and understandable by, both experienced cyclists and non-cyclists. A potential limitation acknowledged within Section 3.3.3 is that despite these efforts made due to the difficulty in attracting non-cyclists to participate in the pilot stages of the research some statements which may have been confusing to non-cyclists were not addressed at this stage.

In some cases existing statements were used to enable comparison with validated measurements or national data; demographic statements were designed to align with the Census (Office for National Statistics, 2011a), physical activity statements to align with the General Practitioner Physical Activity Questionnaire (GPPAQ) (NHS, 2009) and employment questions to align with the National Statistics Socio-economic Classification (NS-SEC) (Rose and Pevalin, 2010).

Additionally the statements regarding attitudes to car use (see Table 4.5 were derived from 'European Golden Questions' development for the SEGMENT project which focused on market segmentation for promoting energy efficient travel (Anable and Wright, 2013).

4.2.3 *Data Collection Waves*

There were two waves of data collection (Wave 1 in September 2015 and Wave 2 in February 2016). The decision to launch the survey in two waves followed the experience of responses relating specifically to cycle path conditions in the winter from the Pilot Survey (3.3). The number of responses in each wave broken down by data collection wave and cycling band is presented in Table 4.1.

	Lower Band	Upper Band	Total
Wave 1	1219	944	2163
Wave 2	1138	1162	2300
Total	**2357**	**2106**	**4463**

TABLE 4.1: Number of completed responses before data cleaning by data collection waves for Upper and Lower band

4.2.4 *The Population and Sampling*

It was decided that this research would investigate the factors influencing the intention to cycle across the population of adults that are physically able to cycle.

Online Access Panel: A random or quota sampling plan based on national demographic proportions from census data might be expected to produce a sample with few existing cyclists due to the low level of cycling in the United Kingdom (see Section 1.3. This sample would likely be biased towards groups 1 and 2 of the Stages of Change subpopulations (Section 2.7.2). On the other hand, due to self-selection, it is likely that an open survey on cycling would provide a sample consisting mainly of existing cyclists due to their interest in the subject. This sample would then be biased towards groups 3 and 4. Neither of these options would be practical when aiming for representation of the four sub-groups. In order to ensure good representation of Upper and Lower Band Cyclists (see Section 3.2.2) an online access panel provided through Respondi (an online market research company based in Germany) was used as this was considered to be a cost-effective and practical way of meeting the research requirements regarding both the number and characteristics of the desired respondents. Respondents are subscribed to a mailing list which provides the opportunity to complete surveys for a small financial reward (Respondi, 2015).

As with any practical option there are weaknesses; for example, this method requires online interaction and as of 2016 11% of households in the UK did not have access to the internet (Office for National Statistics, 2017) and would not be reached by this method. Additionally, access panels tend to attract a higher than representational proportion of middle aged females and respondents from lower income groups to whom the financial reward is more meaningful and who have more flexibility in how their time is used (Brüggen et al., 2011). To ensure that the company which held the panel data had used adequate processes for sampling and data collection, including their methods for accessing hard to reach groups, the potential companies were compared against each other on quality and price. In order to filter out unsuitable companies, a shortlist of companies was chosen from the Market Research Buyers Guide. European Society for Opinion and Market Researching (ESOMAR) has issued ’28 questions to help buyers of online samples’ (ESOMAR, 2012) and companies provide answers to these questions on their websites. Companies which provided satisfactory answers were asked to respond with a quote for providing the required sample. Through this process the company Respondi was chosen due to their acceptable price, ability to conduct the research and accreditations which demonstrated their sufficient quality.

A ‘non-longitudinal’ access panel survey was used with quota sampling based on the equal representation of cyclists and non-cyclists. The quantification of cycling frequency is discussed in section 3.2.2 where the definition of two levels of cycling (Upper and Lower Band) is described. In the light of the experience of the Pilot Survey launch (Section 3.9) the launch of the main survey was designed to avoid underrepresentation of Lower Band cyclists, especially non-cyclists. A target was set for the total sample to include at least 900 respondents that cycled at least once a month and 950 that cycled less than once a month. The minimum sample size recommended for a model with 10 exogenous constructs as used here is 189 ($R2>0.1$, sig. level 5%, statistical power of 80%) (Cohen, 1992; Hair, Mult et al., 2014).

Soft limits were put on the proportions of the respondents which could come from different age groups and the proportion of male or female respondents to restrict the potential for over-representation of sub-groups such as older female respondents who have been found to be more likely to complete online questionnaires (Brüggen et al., 2011). The limits were set above the expected proportions from each group. Lower limits were not set as a narrow focus on age and gender which might lead to increased levels of bias in other areas. Due to the nature of the panel of respondents available to Respondi it was necessary to refine the age range of interest for this research to those aged between 18 and 69. While this does limit the population it was deemed to be acceptable in the context of previous research such as the TfL analysis of cycling potential from 2010 which set a maximum age of 64 when calculating the number of people making potentially cyclable trips (Transport for London, 2010).

No.	Statement	No.	Statement
S1	I feel motivated to cycle/start cycling to improve my fitness	S26	Poor quality surfaces on roads and cycle routes/cause problems for cyclists in my area
S2	I feel motivated to cycle/start cycling because it is good for the environment	S27	The cycle routes in my area are well cleared/gritted in winter
S3	I feel motivated to cycle/start cycling to save money	S28	The cycle routes in my area are attractive and well kept
S4	Many people I know cycle	S29	Cyclists are provided with sufficient protection at roundabouts
S5	In general, I think successful people drive rather than cycle	S30	Cycling journeys in my area are stop-start because cyclists are not given right of way
S6	It's hard to look fashionable when cycling wearing a helmet	S31	It is clear where people are allowed to cycle and where they are not
S7	Cycling is something I want to do	S32	The cycle routes in my area are well joined up
S8	I often have to travel with shopping which is heavy	S33	There are lots of cycle routes where I live
S9	I am unable to cycle due to childcare commitments	S34	Cyclists are protected on roads with fast moving traffic
S10	My day-to-day journeys are too long to cycle	S35	It is easy to find and follow a suitable route when cycling somewhere for the first time
S11	I am physically fit enough to cycle regularly	S36	Car/van drivers give cyclists enough time and space
S12	Cycling is more convenient than driving	S37	Poorly placed street furniture/signs cause obstructions on cycle routes in my local area
S13	Cycling provides people with freedom and independence	S38	The cycle routes in my area protect cyclists from parked cars and opening car doors
S14	The British weather puts me off cycling	S39	It is hard to cycle where I live because there are steep hills
S15	It would be easy for me to fit cycling into my home and work routine	S40	You are vulnerable to violent crime when cycling alone after dark
S16	Cycling is fun	S41	The residential roads in my area are safe for cycling
S17	I would be confident making minor repairs to a bicycle (e.g. a puncture)	S42	You are vulnerable to verbal abuse when cycling
S18	Cycling is more convenient than walking	S43	I have a good space to store a bike at home for day-to-day use
S19	Cycling is more convenient than getting public transport	S44	It is easy to securely park your bike when out and about
S20	My friends and family would/do worry about me getting hurt riding a bike	S45	Cycling in my area is unpleasant due to traffic fumes

No.	Statement	No.	Statement
S21	I'm not the type of person that rides a bike	S46	I am confident sharing the road with traffic when cycling
S22	I was encouraged to cycle when I was a child	S47	Bus/HGV drivers give cyclists enough time and space
S23	A large number of cyclists put themselves and others in danger	S48	Cycling after dark is more dangerous because it is harder for drivers to see you
S24	My friends would approve if I rode a bike/do approve that I ride a bike	S49	Cyclists are provided with sufficient protection at junctions and when crossing side roads
S25	My family would approve if I rode a bike/do approve that I ride a bike		

TABLE 4.2: Survey statements used with all respondents

No.	Statement
Self1	Thinking about if you were to make a journey by bike in your local area... Where 0 = Not at all confident and 10 = Completely confident Out of 10, how confident are you that your journey would be safe?
Self2	Thinking about if you were to make a journey by bike in your local area... Where 0 = Not at all confident and 10 = Completely confident Out of 10, how confident are you that your journey would be comfortable and simple to make?
Child1	Thinking about if a secondary school child (11-16 years old) were to make an unaccompanied journey by bike in your local area... Where 0 = Not at all confident and 10 = Completely confident Out of 10, how confident are you that their journey would your journey would be safe?
Child2	Thinking about if a secondary school child (11-16 years old) were to make an unaccompanied journey by bike in your local area... Where 0 = Not at all confident and 10 = Completely confident Out of 10, how confident are you that their journey would comfortable and simple to make?

TABLE 4.3: Questions relating to respondents' perceptions of safety for themselves and for a hypothetical child

No.	Statement
W1	My place of work/study has good shower/changing facilities
W2	My place of work/study has good bike parking
W3	My place of work/study encourages people to cycle
W4	I would be happy to shower and change clothes at work after cycling into work/study if the facilities were good
W5	I often have to carry equipment for my work which is heavy
W6	I often have to travel during my working day (e.g. between sites or to visit clients)
W7	My colleagues or coursemates would approve if I cycled/do approve that I cycle

TABLE 4.4: Additional survey statements used only with respondents who were in work and who had a fixed workplace

No.	Statement
C1	For most journeys I would rather use the car than any other form of transport
C2	I like to drive just for the fun of it
C3	I am not interested in reducing my car use
C4	Driving gives me a way to express myself

TABLE 4.5: Additional survey statements used only with respondents who had driven within the past year

4.3 Data processing and analysis

4.3.1 *Normality tests*

The data obtained from responses to the attitudinal statements were tested for normality as described in Section 3.2.2. This analysis shows that, in each case, the data cannot be assumed to be normally distributed. An example output for the responses to Statement S1 is shown in Table 4.6.

Statement	S1
Upper Band - Shapiro W statistic	0.886
Upper Band - Shapiro p-value	0
Lower Band - Shapiro W statistic	0.915
Lower Band - Shapiro p-value	0
Combined - Shapiro W statistic	0.916
Combined - Shapiro p-value	0

TABLE 4.6: Example normality test output for the responses to Statement S1

It is commonly found that survey data such as that presented in this thesis is not well modelled by the normal distribution (Bryman, 2016). In this case it may be associated with the use of a forced answer style of survey question, with no provision of a "don't know" option. The relative merits of using of the forced answer style surveys and the provision of "don't know" options have been widely discussed (Bryman, 2016). It was decided not to include a "don't know" option as with these statements being placed at the end of the questionnaire it was felt that non-cyclists may over rely on this if provided. This is supported by Krosnick et al. (2002) which found that don't know responses increase at the end of longer surveys.

4.3.2 *Socio-economic Group*

The NS-SEC simplified derivation (Office for National Statistics, n.d.) was used to classify the socio-economic group of the respondent. Respondents were first asked about their employment status using the categories contained within the Census (Office for National Statistics, 2011b) (see Table 4.19). Respondents that stated that they were employed were then directed to further questions according to the NS-SEC and asked to for details on their employment type (see Table 4.20), the size of the company they worked for, whether the respondent was an employee or employer and whether or not they supervised others.

Based on their answers to these questions respondents are allocated classifications based on a) their self reported employment type and b) their position within the company they work for and the size of that company. These are then combined into a single classification using the matrix set out in (Office for National Statistics, n.d., Table 6).

These derived classifications were then combined with the non-employed classifications set out in Table 4.19 to provide classifications for the whole dataset which provides a more detailed picture of the make up of the sample (see Table 4.21).

A scale rather than a single question on household income was used for two main reasons:

1. There are insights to be gained from considering cycling behaviour across different job types as well as income levels or household class. For instance, shift workers may cycle due to a lack of public transport available at the times they need to travel to and from work (Jones and Lucas, 2012).

2. Some respondents can be unwilling or unable to provide information on their household income or may not know the detailed information about others in their household required for a NS-SEC classification of household class, which would reduce the proportion of the dataset which could be classified.

Thus, rather than a description of socio-economic class this should be treated as a more detailed version of the employment status question. The representativeness of the data in comparison to the population is estimated in Section 4.3 and Section 4.4.

A disadvantage of this method is that, as the job type relates only to the person completing the survey, it does not allow the differentiation of households. If there are other adults working in their household this could greatly affect their lifestyles, but would not be represented in this data; this reduces the comparability of this analysis to other research which uses household class or household income as a measure of social class. It was felt that, as the interest in this research was on the individual's travel behaviour, that this limitation was compensated by the additional information which could be collected about the individual respondent.

4.3.3 *Place of Residence*

The use of their self-reported place of residence (at a Postal District level) to provide the basis for a measure of the cycling infrastructure in their area is also described in the previous chapter (Section 3.2.1).

This dataset was designed to cover the United Kingdom with responses accepted from England, Scotland, Wales and Northern Ireland. In order to identify how the demographic spread of the dataset compared to the population, chi-square tests were conducted to detect whether there were significant differences in the distribution. The dataset used for the comparison were the population estimates which are published annually. They are based on the population figures from the 2011 census and updated to reflect trends in population growth and movement (Office for National Statistics, 2016), the 2015 figures were used as the closest iteration to the data collection period and the comparison was based on the Government regions. The respondents provided the Government region within which they lived at the screening stage of the survey. Within the main body of the survey they provided their postal district which was used to confirm the accuracy of their self-reported Government region. The responses are summarised in Table 4.7 which demonstrates the geographical spread. Chi-Square tests (χ^2 = 80.4 - significant to 95%) indicate that there is a significant difference between the distributions. Testing the relationship for each region individually in comparison to the rest of the population as a two group test indicates that the largest differences are an over-representation of respondents from the North East (χ^2 = 11.7 - significant to 95%) an and under-representation of respondents from London (χ^2 = 34.9 - significant to 95%).

There was over representation of North East and North West and underrepresentation of London and South East apart from Wave 2 (Feb) Upper Band.

Region	Wave 1	Wave 2	Total	Proportion	Expected Proportion	χ^2	P - value
North East	89	107	196	0.051	0.041	11.7	<0.001
North West	207	260	467	0.123	0.11	6.0	0.01
Yorkshire and The Humber	149	172	321	0.084	0.083	0.1	0.75
East Midlands	145	158	303	0.08	0.072	3.6	0.06
West Midlands	143	184	327	0.086	0.088	0.1	0.72
East	146	154	300	0.079	0.092	7.9	0.005
London	196	202	398	0.105	0.138	34.9	<0.001
South East	251	321	572	0.15	0.136	6.6	0.01
South West	138	219	357	0.094	0.082	6.8	0.01
Scotland	135	164	299	0.079	0.084	1.3	0.25
Wales	82	108	190	0.05	0.047	0.6	0.45
Northern Ireland	40	37	77	0.02	0.029	9.5	0.002
Total	**1721**	**2086**	**3807**	**-**	**-**	**-**	**-**

Wave	Band	Test	n	P - value
1 (September)	Upper Band	Chi-Square	815	<0.01
1 (September)	Lower Band	Chi-Square	906	0.11
2 (February)	Upper Band	Chi-Square	1028	<0.01
2 (February)	Lower Band	Chi-Square	1058	<0.01

TABLE 4.7: Expected and actual respondent numbers by Government Region for the complete dataset, with Chi square test for Wave 1 and 2, Upper and Lower Band respondents

For some analysis the data was divided into geographic areas based on the respondents' response to 'Which of these best describes the area in which you live?'. For this grouping respondents who reported living in Greater London were grouped separately. The area types used and the number of respondents within each group are shown in Table 4.8.

Area	n	%
Greater London	398	10.5%
Non-London Urban	1077	28.5%
Non-London Suburban	1433	37.9%
Non-London Rural	875	23.1%

TABLE 4.8: Respondents grouped by urban/rural area type (Greater London grouped separately)

4.3.4 *Cycling Behaviour*

Self-reported cycling behaviour is measured in more than one way within this survey. In the screener section of the survey, respondents are asked about their normal level of cycling in the winter and summer months. This measure was used to capture the differences in cycling behaviour, with more committed cyclists more likely to cycle regularly in winter as well as in summer. Within the questions from the GPPAQ, the amount of cycling within the past week is asked. This provides a check on how those that report cycling regularly in the screener question across the two waves of data collection. In order to test whether there were differences between the level of correlation between the self-reported level of cycling in warmer and colder months and the self-reported level of cycling in the past week, Spearman's rank correlation coefficients were calculated as described in Section 3.7.5.

As both of these measures cover both recreational and utility cycling, a strong level of correlation would be expected. As shown in Figures 4.1 and 4.2, Spearman's rank tests show that there is a strong correlation between the reported cycling in the past week and the usual level of cycling in winter and summer months. This suggests consistency within the data and that the usual behaviour measure is likely to be fairly accurate. The correlation is slightly lower within the February data, which is likely due to the poorer weather in February.

The correlation between the measure used to establish the Intention to Cycle for utility journeys and these measures is also shown in 4.1 and 4.2. As expected this correlation is weaker than the correlation between the different measures of all cycling, with only a medium level correlation between hours cycled last week and Intention to Cycle for utility trips in February. This supports the use of a separate

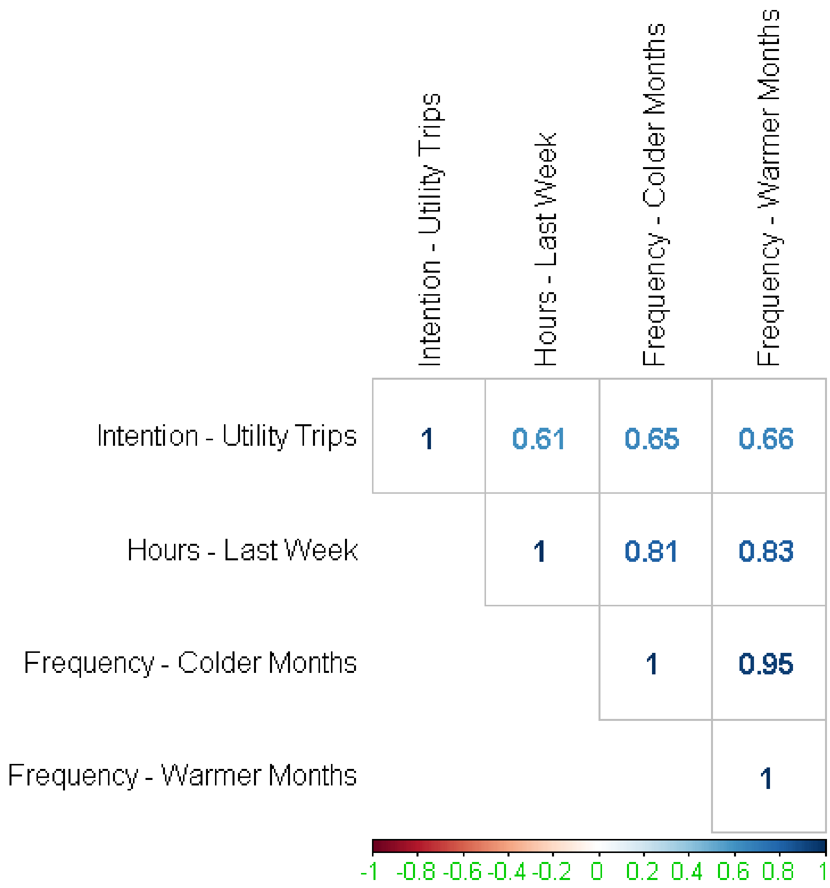


FIGURE 4.1: Correlation coefficients for measures of cycling - Wave 1 (September)

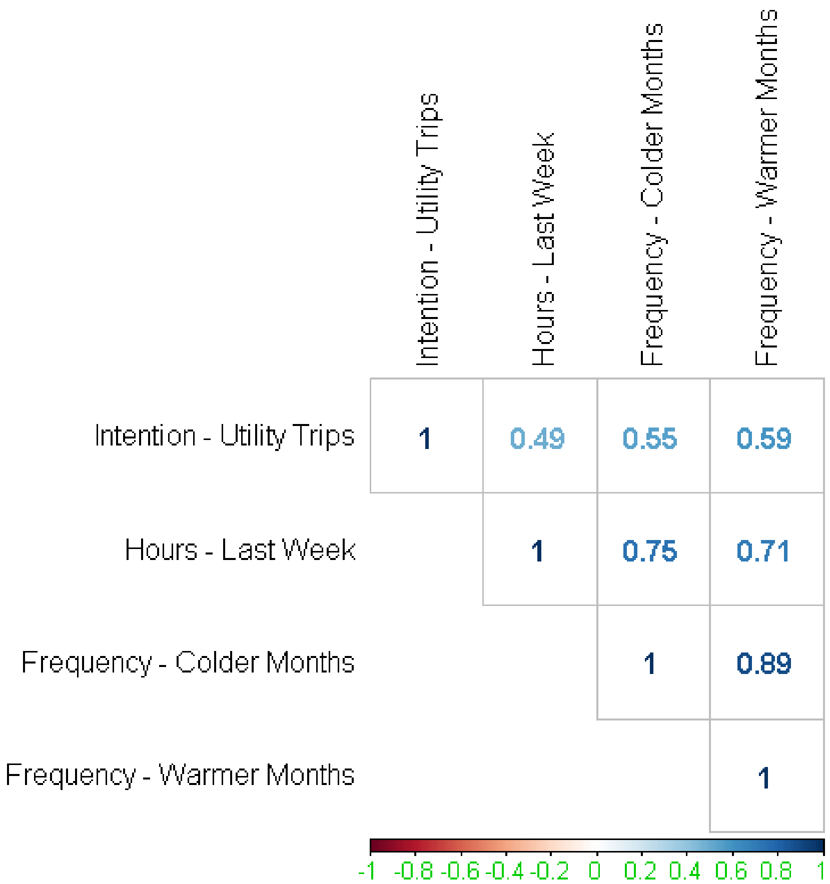


FIGURE 4.2: Correlation coefficients for measures of cycling - Wave 2 (February)

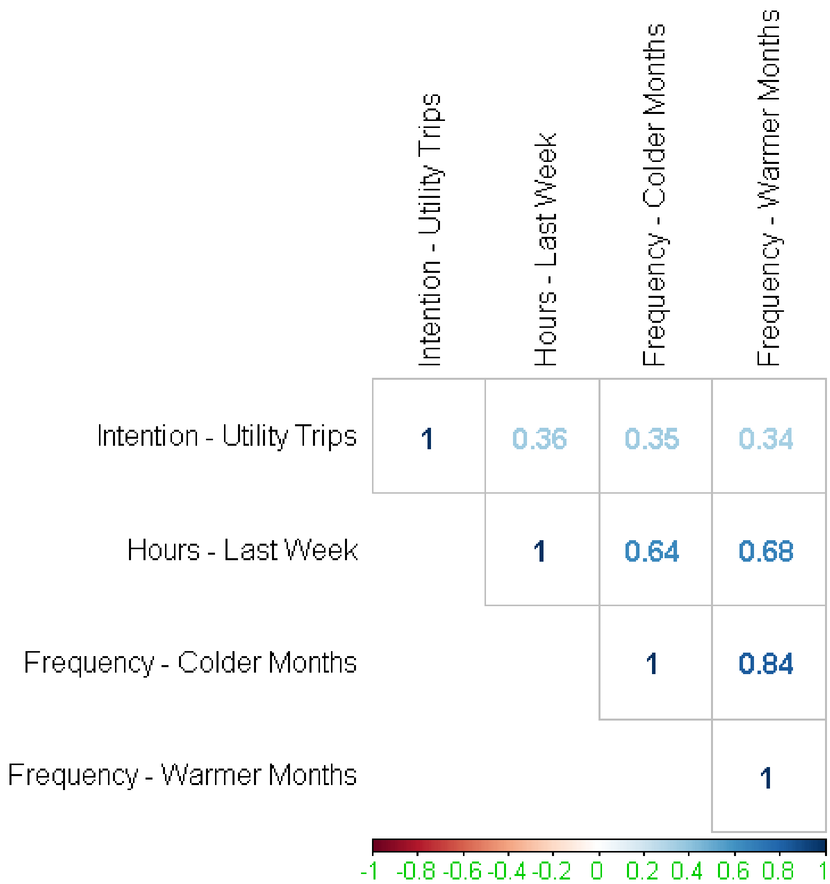


FIGURE 4.3: Correlation coefficients for measures of cycling - Mainly leisure

measure of Intention to Cycle for utility journeys, which are the topic of interest for this work, as this may indicate they are successfully measuring different behaviours.

Figures 4.3 and 4.4 show the correlation coefficients with non-cyclists removed from the dataset and the cyclist respondents divided into 'mainly leisure' and 'mainly utility' cyclists. One group are those that reported making half or most of their cycling journeys for leisure (leisure cyclists), the other group reported making at least half of their journeys for utility purposes (utility cyclists).

While the associations within these two groups separately are lower than the when the dataset is analysed as a whole the stronger correlation for cyclists that reported that their cycling journeys are mainly for utility rather than leisure also supports the conclusion that the intention to cycle for utility journeys is a separate measure from an individuals overall cycling frequency.

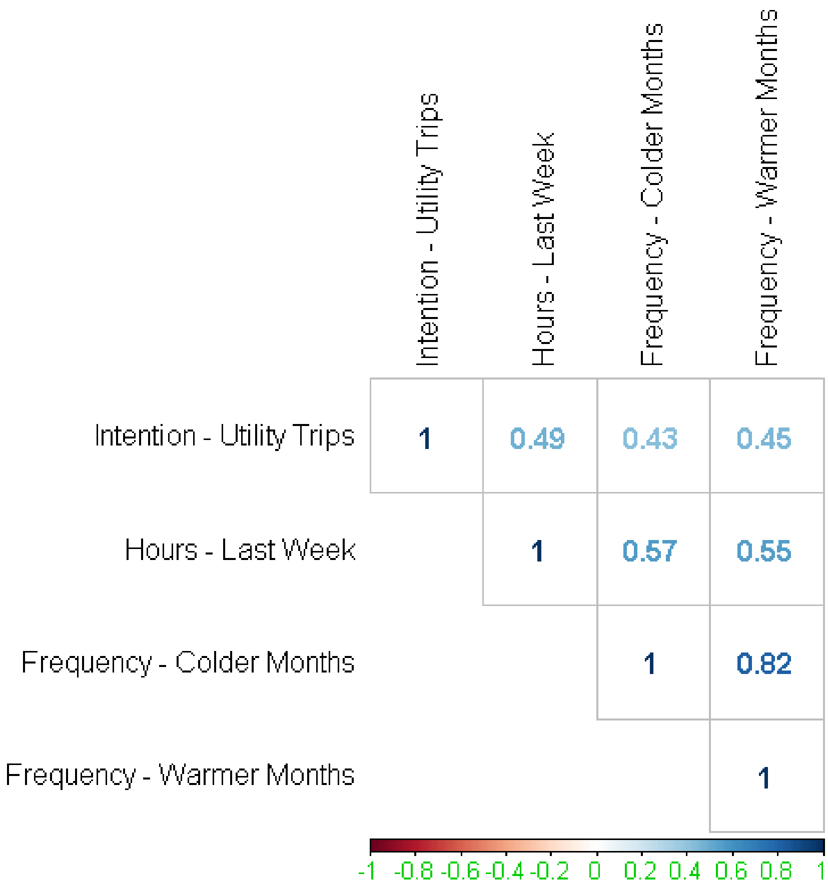


FIGURE 4.4: Correlation coefficients for measures of cycling - mainly utility

4.3.5 *Gender, age and ethnicity*

Tables 4.10, 4.12 and 4.13 summarise the extent to which the sample (broken down by Wave and by Cycling Band) was representative of national demographic data for the UK population. The population data has been filtered to include only those aged 18-69 where possible as this restriction was put on the survey data.

The number of responses broken down by gender are shown in Table 4.9 for the Upper and Lower Band cohorts. Table 4.10 shows that the sample was generally representative gender split. However, there is a significant over-sampling of females within the Wave 2 (Feb) data with Lower Band.

The number of responses broken down by age group are shown in Table 4.11 for the Upper and Lower Band cohorts. The sample is significantly different to the population when considering age as shown in Table 4.12. However, the patterns match those expected based on cycling data, with an overrepresentation of younger age groups in the Upper Band.

Table 4.13 shows that when considering ethnicity, the sample is significantly different to the population containing an over representation of white respondents (χ^2 = 184.4, p-value <0.01). This may be a feature of the panel used to collect the sample.

Thus, comparing the dataset to national figures shows that, while there are significant differences between the national level data and this dataset in some areas, the data contains adequate response levels to compare respondents' perceptions by age and gender and to use the place of residence to test the impact of infrastructure in comparison to these perceptions.

	Upper Band	Lower Band	Total
Male	901	914	1815
Female	942	1050	1992
Total	**1843**	**1964**	**3807**

TABLE 4.9: Number of responses by gender for Upper and Lower band

Dataset	Test	P - value
Wave 1 (Sept) – Upper Band	Chi-Square	0.22
Wave 1 (Sept) – Lower Band	Chi-Square	0.77
Wave 2 (Feb) – Upper Band	Chi-Square	0.515
Wave 2 (Feb) – Lower Band	Chi-Square	<0.01

TABLE 4.10: Summary Statistics for Gender Representation

	Upper Band	Lower Band	Total
18-25	245	190	435
26-34	321	244	565
35-44	405	324	729
45-54	414	412	826
55-64	344	500	844
65-69	114	294	408
Total	**1843**	**1964**	**3807**

TABLE 4.11: Number of responses by age group for Upper and Lower Band

Dataset	Test	P - value
Wave 1 (Sept) – Upper Band	Chi-Square	<0.01
Wave 1 (Sept) – Lower Band	Chi-Square	<0.01
Wave 2 (Feb) – Upper Band	Chi-Square	<0.05
Wave 2 (Feb) – Lower Band	Chi-Square	<0.01

TABLE 4.12: Summary Statistics for Age Representation

Ethnicity	n	%
White, British	3334	87.58
Other White	190	4.99
Mixed - Black	29	0.76
Mixed - Asian	18	0.47
Mixed - Other	15	0.39
Asian/Asian British	127	3.34
Black/Black British	58	1.52
Arab	1	0.03
Other	35	0.92

TABLE 4.13: Summary Statistics for Ethnicity Representation

4.4 Further respondent characteristics

As well as the top level demographic characteristics described above other further information was collected which was not compared to national data. While national level data is available for these characteristics it was judged that due to potential complex interactions between these variables tests are presented only for the variables included within the screener section of the survey (age, gender, region and cycling frequency) which were used either by the panel company or the researcher as part of the sampling and/or quota management process.

Summaries of the main respondent characteristics collected but not compared to national data are presented below.

4.4.1 *Mobility*

Respondents were asked whether they had mobility issues which restricted their use of different modes of transport. As an individual can have an issue which restricts their use of multiple modes this question was asked in a multiple response format. 84.9% of respondents reported that did not have a mobility issue which restricted their use of any of the modes of transport listed in Table 4.14. The options listed was chosen to reflect the modes commonly used for journeys which may seen as of a cycleable length, as such modes commonly used for longer distances such as rail and coaches were not listed.

'Restricted' Mode of Transport	Frequency	Percent of Cases	Percentage of Respondents (n = 3597)
On Foot	456	12	12.7
Local busses	281	7.4	7.8
Car	229	6	6.4
Bike	437	11.5	12.1
None of these	3055	80.2	84.9
Prefer not to Say	70	1.8	1.9
Total	**4528**	**118.9**	**-**

TABLE 4.14: Proportion of respondents which reported mobility issues which restricted their use of different transport modes

4.4.2 *Physical activity*

Within the questionnaire, scales were used to measure weekly physical activity and job type. The GPPAQ (NHS, 2009) was used to measure physical activity. The questions include:

- the amount of activity at work
- Time spent walking, cycling and household activity and other physical activity in the past week
- Walking pace

The responses to the number of hours spent cycling or partaking in physical activity and the amount of activity at work are then combined as set out in (NHS, 2009, Annex 1B) This approach was chosen, rather than the use of a single question covering the total amount of physical activity, as it is a validated screening tool which provides a richer source of information (NHS, 2009). It was felt that each of these aspects of physical activity were of valid interest within this research separately and could provide sense- checks against other questions elsewhere in the questionnaire (such as level of cycling in the past week against reported cycling in the past year). However, for the second wave of the data collection, it was necessary to add two attitudinal questions relating to the subjective norm (see Section 3.2). In order to enable the inclusion of these, statements relating to walking pace and to the amount of gardening and other household activity in the past week were removed. This did not affect the calculation of the GPPAQ activity classifications as they were found not to be reliable measures (NHS, 2009) although their removal does reduce the consistency with the presentation of the original scale.

The responses, categorised through the GPPAQ are shown in Table 4.15. The activity classifications are shown separately for the sample for each data collection cohort. This classification shows that the cohort of more frequent cyclists is more active than the less frequent/non-cyclists within the overall dataset. This indicates that within this dataset there is no evidence of activity compensation (Green et al., 2014) though we do not know if those that are currently cycling have replaced a former type activity.

Activity Level	Upper Band	Lower Band	Whole Dataset
Inactive	122	815	937
Moderately Inactive	155	316	471
Moderately Active	269	280	549
Active	1248	392	1640
Total	**1794**	**1803**	**3597**

TABLE 4.15: Activity level classification (Calculated using GPPAQ) (NHS, 2009)

4.4.3 *Bicycle ownership*

Table 4.16 summarises the frequency of bicycle ownership among respondents. This shows that over half of respondents owned a bike themselves (54.6%). When split by cycling level bike ownership was unsurprisingly much more common among the Upper Band data cohort with 88.8% owning a bike compared to 22.6% of those cycled less frequently or never.

A Chi-Squared test was used to compare for significant differences in the response patterns across the area types shown in Table 4.8. This showed that the samples could only be assumed to be independent in relation to respondents reporting access to a bike hire (χ^2 = 70.6 - sig <0.01 - London: 7.3% Other Areas 0.9% - 1.7%) and pool schemes (χ^2 = 18.8 - sig <0.01 - London: 2.3% Other Areas 0.3% - 0.6%) with higher proportions reporting access to these in London than other areas.

Form of Access	Frequency	Percent of Cases
Own a bicycle yourself	2080	54.6
Sign up to a bike hire scheme (e.g. Santander Cycles, Bike & Go)	73	1.9
Access to pool bikes through work/study	25	0.7
Share a bicycle or have easy access to a bicycle owned by someone else	131	3.4
Have limited access to a bicycle owned by someone else	124	3.3
Have no access to a bicycle	1482	38.9
Total	**3915**	**102.8**

TABLE 4.16: Bicycle Ownership among all respondents

4.4.4 *Car ownership*

Respondents were asked about car ownership. In Table 4.17 the level of car ownership for both cohorts (Upper and Lower Band) is compared. While the Chi-Squared test shows that the two datasets can be assumed to be independent (χ^2 = 31.46 - sig <0.01) the distribution of car ownership appears to follow a similar structure for cyclists and non-cyclists. Non-cyclists are more likely not to have a car in their household (21.84% compared to 16.77%). Thus, it is unlikely that the higher levels of cycling are driven by the lack of alternatives.

	Upper Band		Lower Band	
Number of cars	n	%	n	%
None	309	16.77	429	21.84
One	857	46.5	964	49.08
Two	530	28.76	448	22.81
Three	106	5.75	84	4.28
Four or more	41	2.22	39	1.99

TABLE 4.17: Car ownership among More Frequent Cyclists (Upper Band) and Less Frequent Cyclists (Lower Band)

4.4.5 *Travel Behaviour*

In order to get a picture of how the respondents travelled they were asked how frequently they travelled by each mode. The same levels of frequency were used for each mode as was used for the level of cycling in warmer and colder months within the screener section of the survey. The responses are shown in Table 4.18.

	Sample	At least once a day	Less than once a day, but at least 3 times a week	Once or twice a week	Less than that but more than twice a month	Once or twice a month	Less than that but more than twice a year	Once or twice a year	Less than that or never
		Frequency of Travel							
		n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Car, as driver	Upper Band	760 (41%)	316 (17%)	194 (11%)	47 (3%)	28 (2%)	43 (2%)	23 (1%)	432 (23%)
	Lower Band	754 (38%)	311 (16%)	173 (9%)	52 (3%)	31 (2%)	32 (2%)	36 (2%)	575 (29%)
Car, as passenger	Upper Band	165 (9%)	296 (16%)	482 (26%)	277 (15%)	223 (12%)	178 (10%)	72 (4%)	150 (8%)
	Lower Band	148 (8%)	293 (15%)	417 (21%)	270 (14%)	268 (14%)	230 (12%)	125 (6%)	213 (11%)
Local public transport	Upper Band	180 (10%)	183 (10%)	243 (13%)	225 (12%)	241 (13%)	248 (13%)	201 (11%)	322 (17%)
	Lower Band	188 (10%)	171 (9%)	222 (11%)	202 (10%)	207 (11%)	265 (13%)	226 (12%)	483 (25%)
Long distance public transport	Upper Band	53 (3%)	62 (3%)	92 (5%)	152 (8%)	213 (12%)	453 (25%)	409 (22%)	409 (22%)
	Lower Band	38 (2%)	21 (1%)	44 (2%)	84 (4%)	152 (8%)	445 (23%)	458 (23%)	722 (37%)
Walking	Upper Band	1104 (60%)	350 (19%)	224 (12%)	74 (4%)	31 (2%)	11 (1%)	10 (1%)	39 (2%)
	Lower Band	958 (49%)	369 (19%)	264 (13%)	92 (5%)	61 (3%)	38 (2%)	24 (1%)	158 (8%)

TABLE 4.18: Frequency of travel mode for Upper and Lower Band respondents

4.4.6 *Employment Status and Job Type*

Respondents were asked about their employment status (Table 4.19) and job type, based on a standard list to be used with the NS-SEC classification (Rose and Pevalin, 2010) (Table 4.20). Almost half (46.1%) of respondents reported working full time with a further 16.7% reporting that they worked part time.

Within the employed population the highest proportions of were 'Modern Professional Occupations' and 'Clerical and intermediate occupations', but there was a reasonable spread of responses from every category.

These job categories were then classified alongside information about the size of the company and whether the respondent was an employee or employer and whether or not they supervised others based on the National Statistics Socio-economic classification NS-SEC classifications (5 levels). This was then combined to give a 10 level summary which covered all the respondents (Table 4.21).

	n	%
Working full time (30 hours or more a week)	1755	46.10%
Working part time (Less than 30 hours a week)	634	16.65%
Unemployed and looking for work	135	3.55%
In education	139	3.65%
Looking after family or home	251	6.59%
Unemployed and not seeking work	175	4.60%
Retired	639	16.78%
None of the above	57	1.50%
Prefer not to say	22	0.58%

TABLE 4.19: Respondent Employment Status (% corrected for valid responses from individuals in employment)

	n	valid %
Modern professional occupations e.g. Teacher, nurse, police officer (sergeant or above), software designer	473	19.80%
Clerical and intermediate occupations e.g. Secretary, personal assistant, clerical worker, call centre agent	513	21.47%
Senior managers or administrators e.g. finance manager or chief executive	199	8.33%
Technical and craft occupations e.g. Motor mechanic, plumber, gardener, train driver	190	7.95%
Semi-routine manual and service occupations e.g. Postal worker, machine operative, security guard, caretaker, farm worker, receptionist or sales assistant	372	15.57%
Routine manual and service occupations e.g. HGV driver, cleaner, labourer, waiter/waitress or bar staff	215	9.00%
Middle or junior managers e.g. Office manager, retail manager, bank manager, restaurant manager, warehouse manager, publican	304	12.72%
Traditional professional occupations e.g. Accountant, solicitor, medical practitioner, civil/mechanical engineer	123	5.15%

TABLE 4.20: Respondent Employment Type (% corrected for valid responses from individuals in employment) based selection from eight options indicated.

	n	%
Managerial, administrative and professional occupations	1135	29.81%
Intermediate occupations	397	10.43%
Small employers and own account workers	206	5.41%
Lower supervisory and technical occupations	207	5.44%
Semi-routine and routine occupations	444	11.66%
Students	139	3.65%
Homemaker or carer	251	6.59%
Retired	639	16.78%
Unemployed	310	8.14%
Unclassified	79	2.08%

TABLE 4.21: Respondent employment classification based on the National Statistics Socio-economic classification (NS-SEC) (% corrected for valid responses from individuals in employment)

4.4.7 *Commute*

Respondents were asked about their regular commute. 46% reported having a fixed commute distance which is 5 miles or less which is target distance for cycling. The results are summarised in Table 4.22.

Of those that had a usual place of work and usual commuting time the peak time for starting the commute was between 07:00 and 08:59 with 64% of respondents starting their commute between these times suggesting that the majority work normal office hours.

	n	%
Work mainly from home	244	9.65%
No usual place of work or study	112	4.43%
Less than 2 miles	555	21.95%
2 to less than 5 miles	608	24.05%
5 to less than 10 miles	493	19.50%
10 miles or more	500	19.78%
Don’t know	16	0.63%

TABLE 4.22: Regular Commute Distance as Reported by Respondents

4.5 Summary and Discussion

A significant methodological choice within this research was the choice to use an online non-longitudinal panel to reach the breadth of cyclists and non-cyclists required to meet the aim of this research. This method successfully allowed for the collection of data from a wide range of cycling frequencies and a breadth of socio-demographic groups. However, the sample collected did include an underrepresentation of younger respondents, ethnic minorities and respondents from London. This may limit the potential of the findings of this study to be generalised across the population. These issues could be partially addressed through the development of a more restrictive specification of quotas, however this would increase the risk of unintended bias and increase the cost and time taken for the data collection process.

Chapter 5. Analysis of Attitudinal Statements

5.1 Introduction

The previous chapter set out the data collection process and described the sample demographics and established how representative the sample is of the population. This found that, while there were significant differences between the makeup of the sample and the population, the sample was broadly representative.

This chapter analyses the responses to the attitudinal statements which were included in the questionnaire. These statements were designed to cover the constructs which the literature suggested may affect cycling behaviour. Each construct is presented in turn with analysis of the individual statements. The response patterns are presented and analysed first for the overall dataset and then broken up by cycling level, age, gender and other subgroups where appropriate.

As described in Section 3.6.1. two different approaches are used within this thesis for subdividing the dataset by cycling frequency based on the needs of the analysis:

- In Section 5.2, which analyses the Intention to Cycle for utility journeys, two subsets are used (Upper and Lower Band cyclists).
- In order to highlight differences in the views of those who never cycle from the views of those who cycle occasionally and those that cycle Frequently , three groups (F=frequent, O=occasional and N=non-cyclists) are used within Sections 5.3 and 5.4. These sections analyse responses to the statements regarding 'Hard' and 'Soft' factors.

5.2 Intention to Cycle

The scale used to measure the Intention to Cycle was based upon the stages of change model and applied as described in Section 3.2.2. The options and the responses are summarised in Table 5.1.

Two respondents who, based on their response to the screener questions relating to cycling frequency analysed in Section 4.3.4, were identified as being from the Lower Band, indicated that they have been making their everyday journeys by bicycle for some time. By checking their answers to the other questions within the survey we can see that these respondents reported that they had not cycled in the past week and that they did not usually cycle more than once or twice a year. While these responses initially seem counterintuitive, they may be explained by considering that these respondents may be taking a longer term view of their travel behaviour than was expected when the question was written and have made journeys by bike in the past and had not intentionally stopped doing so. On the other hand, the response may indicate a mistaken response or a poor quality response that was not picked up within the data quality checks. As these respondents had met the quality checks set out in Section 3.6 and there is an explanation for their responses, the data for these two individuals was retained.

	Data Collection Cohorts		
Thinking about your everyday journeys (e.g. to work or the shops) which of these statements best applies to you?	Upper Band	Lower Band	Total
I have not thought about making my everyday journeys by bicycle	472 (25.6%)	1378 (70.2%)	1850 (48.6%)
I never make my everyday journeys by bicycle, but sometimes consider it	323 (17.5%)	307 (15.6%)	630 (16.6%)
I sometimes make my everyday journeys by bicycle, but I am not thinking about doing so more regularly	314 (17%)	38 (1.9%)	352 (9.2%)
I sometimes make my everyday journeys by bicycle, and I am seriously thinking about doing so more regularly	292 (15.8%)	27 (1.4%)	319 (8.4%)
I have recently started making my everyday journeys by bicycle	62 (3.4%)	4 (0.2%)	66 (1.7%)
I have been making my everyday journeys by bicycle for some time and I plan to continue doing so	248 (13.5%)	0 (0%)	248 (6.5%)
I have been making my everyday journeys by bicycle for some time but would like to do so less regularly	13 (0.7%)	2 (0.1%)	15 (0.4%)
I used to make my everyday journeys by bicycle and would consider doing so again	81 (4.4%)	66 (3.4%)	147 (3.8%)
I used to make my everyday journeys by bicycle and would not consider doing so again	38 (2.1%)	142 (7.2%)	180 (4.7%
Total	**1843 (100%)**	**1964 (100%)**	**3807 (100%)**

TABLE 5.1: Responses to Intention to Cycle

These responses were recoded to create a scale from the lowest to the highest Intention to Cycle for use in the path modelling analysis. For this recoding the respondents who said they used to cycle were recoded in line with whether they were considering starting again. Those that responded “I used to make my everyday journeys by bicycle and would not consider doing so again” were added to the group which said “I have not thought about making my everyday journeys by bicycle”.

Those that responded “I used to make my everyday journeys by bicycle and would consider doing so again” were grouped with those that responded ”never make my everyday journeys by bicycle, but sometimes consider it”.

5.2.1 *Leisure and Utility Cyclists*

The Upper Band contained 1843 respondents. Almost half of these (914, 49.6%) do not make their every day journey by bike. Furthermore, a majority (510, 55.8%) of these frequent cyclists who do not make their everyday journey by bike have not thought about making their everyday journeys by bike. Within the screener section of the questionnaire, respondents were asked what proportion of their journeys were for leisure. A majority (72%) of the Upper Band that said they had not thought about making their regular journeys by bike also reported that all or almost all of their cycling trips in warmer months were for leisure. Only 12% of these respondents reported that fewer than half of their cycling trips were not for leisure.

The respondents who reported both not thinking about making their everyday cycling trips by bike and making fewer than half of their leisure trips by bike could make the majority of their journeys by bike for purposes they would not class as leisure or as everyday, for example cycling for fitness purposes.

Alongside the correlation tests presented in Section 4.3.4, this analysis shows that the use of the stages of change scale appears to differentiate between leisure cyclists and utility cyclists. These results also suggest that, even within the cohort of frequent cyclists, there is a potentially substantial number who may regard cycling only as a leisure activity unconnected to their utility journeys.

5.2.2 *Stages of Change among Non-Cyclists*

As discussed within the Literature review (Chapter 2) much of the existing research which looks to determine the influences on cycling behaviour through survey methods focusses solely on existing cyclists (Willis, Manaugh and El-Geneidy, 2015; Aldred, Elliott et al., 2016).

This limits the insights which can be made into which aspects act as barriers or attractors to those who currently do not cycle. While the opinions of cyclists are valuable in determining what improvements can be made to their experience (Aldred, 2013) it is important that the views of potential cyclists are not ignored. Without understanding how the issues which are important at different stages of the transition for non-cyclist to cyclist, there is a danger of developing an environment which only suits those that have already made the change and does not attract others.

An important reason for adopting questions based on Stages of Change was to attempt to differentiate between those who never cycled and are not considering it on one hand and those who do not currently cycle, but are considering it on the other.

This would not be possible using a scale which measured frequency alone. Among non-cyclists, a very high proportion report they have not thought about making their journeys by bike (83%). This suggests that the wording of the question may not have fully differentiated between those that would never consider cycling and those that those that may consider cycling if the circumstances were right. Within the Stages of Changes structure, both of these groups would be classed as within the 'precontemplation' stage (Prochaska and Velicer, 1997) and thus it may be appropriate that they are grouped together. However, this limitation will be noted in subsequent discussion of the results. This pattern, with one option dominating the response for Lower Band respondents, also supports the use of the Partial Least Squares (PLS) approach to structural equation modelling (see Chapter 6) due to the stricter distributional assumptions required for covariance based-structural equation model (Hair, Mult et al., 2014), however it may still limit the insights which can be gained from this analysis to some extent.

Separate categories were included for those that had previously made their journeys by bike. This comparison shows that the majority (70%) of the Lower Band group have not thought about making their regular journeys by bike with an additional 7% of respondents reporting that they previously cycled but would not consider doing so again.

5.3 Perception of the Environment

Respondents were also asked about their perceptions of the local cycling environment. This was presented in two ways within the questionnaire:

1. **Overall Perceptions:** Initially respondents were asked to consider how 'safe' and 'simple and comfortable to make' a cycle journey in the local area would be for them and also for a secondary aged child (11-16) cycling alone. This was presented on an 11 point scale ranging from 0 - 10.
2. **Specific Elements within CROW guidance:** Later in the survey respondents were presented with a series of 25 statements about a cycling environment and asked, when thinking about their local area, how strongly they agreed or disagreed with each statement using a 7 point Likert scale. These statements were designed to fit within the CROW framework of Safety, Coherence, Directness, Comfort and Attractiveness.

Due to the similarity of some of the elements, the factors were grouped into 'safety', 'comfort and attractiveness' and 'coherence and directness' when comparing the response patterns to each statement.

5.3.1 *Overall Perceptions of Journey Quality*

The decision to ask the same questions, but with respondents considering first themselves and then an 11-16 year old child cycling alone, allows an analysis of the difference between these two measures and consideration of the possible causes for any difference between the response patterns. Table 5.2 and Figure 5.1 show the responses for the question relating to the respondent making a journey in their local area, Table 5.3 and Figure 5.2 show the responses to the question asking respondents to imagine an unsupervised child making a journey.

Confidence	Cycling Frequency			Total
	Non-cyclists	Occasional cyclists	Frequent cyclists	
0	30.9%	7.2%	4.1%	16.4%
1	5%	4.4%	2.4%	4%
2	10.1%	8.8%	3.7%	7.6%
3	8.9%	8.6%	4.4%	7.2%
4	5%	7.4%	4.9%	5.5%
5	10.6%	11.9%	9.8%	10.6%
6	6.2%	11.2%	9.3%	8.4%
7	7.6%	14.3%	16.3%	12.1%
8	7.7%	13.2%	19.1%	12.9%
9	3.6%	7.3%	12.4%	7.5%
10	4.4%	5.8%	13.7%	8%
Total n	**1647**	**825**	**1335**	**3807**

TABLE 5.2: Confidence a journey in the local area would be safe - by cycling level

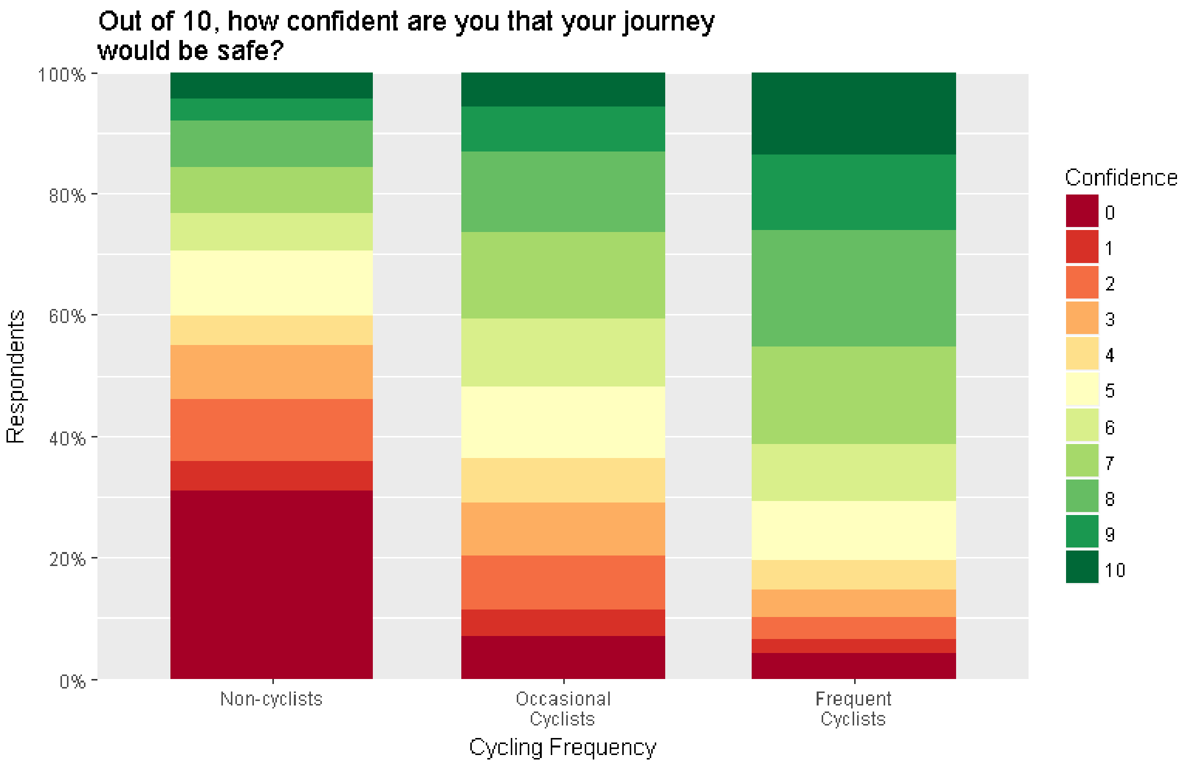


FIGURE 5.1: Confidence a journey in the local area would be safe - by cycling level

Confidence	Cycling Frequency			Total
	Non-cyclists	Occasional cyclists	Frequent cyclists	
0	24.6%	11.4%	8.2%	16%
1	7.8%	6.3%	5.2%	6.6%
2	9.8%	10.7%	7%	9%
3	9.5%	10.3%	6.8%	8.7%
4	8.6%	11.2%	7.9%	8.9%
5	14%	17.5%	15.3%	15.2%
6	7.3%	8.2%	12.8%	9.4%
7	7.2%	10.3%	13%	9.9%
8	6.9%	7.9%	12.7%	9.1%
9	1.9%	3.8%	5.2%	3.5%
10	2.5%	2.5%	5.8%	3.7%
Total n	**1647**	**825**	**1335**	**3807**

TABLE 5.3: Confidence a journey in the local area would be safe for 11-16 year old child - by cycling level

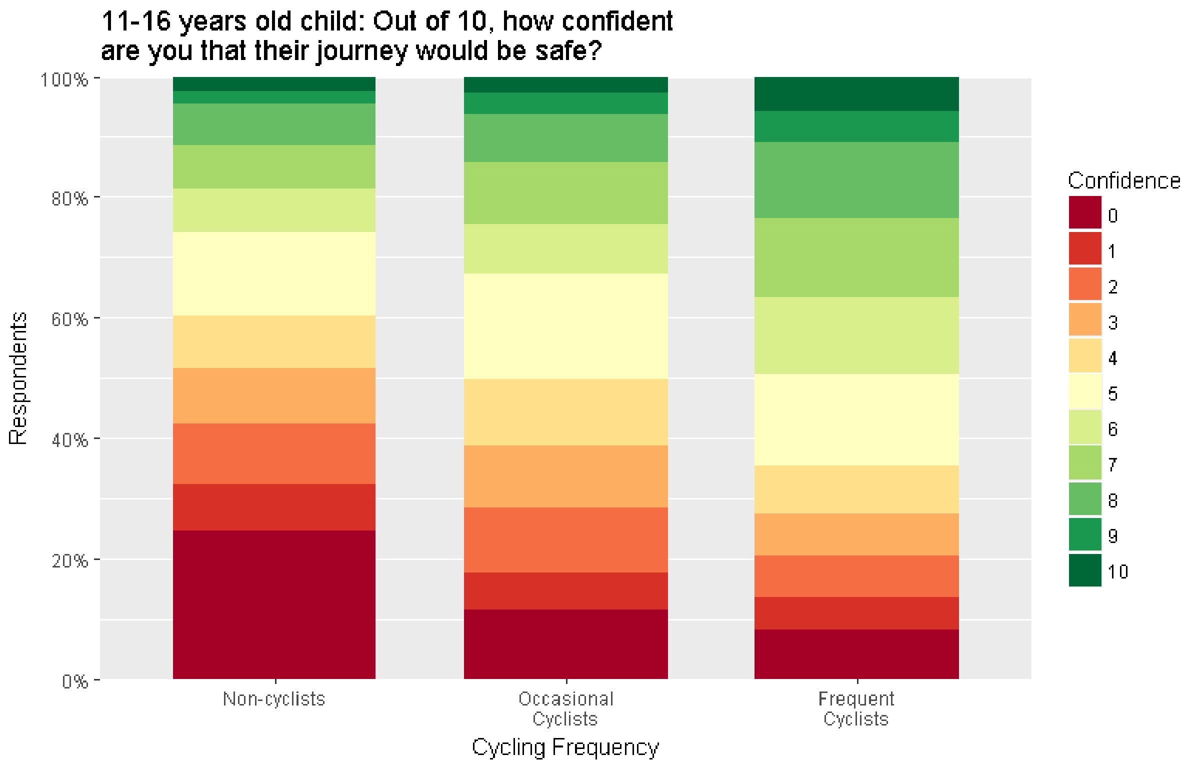


FIGURE 5.2: Confidence a journey in the local area would be safe for 11-16 year old child - by cycling level

Table 5.4 and Figures 5.1 and 5.2 show that there are clear differences between the responses for respondents across different cycling levels. For all groups there is a large number of respondents choosing the middle of the scale (5), perhaps suggesting that some respondents may have treated this as a 'don't know'/'no opinion' option.

The clearest response pattern which can be drawn from this question is the high proportion of non-cyclists responded 0 for their confidence that the journey would be safe. This pattern is present for both questions, but more starkly present when non-cyclists were asked to think about themselves making the journey. This was unexpected as it had been anticipated that each group would feel that the child cycling alone would have been less safe. This could be of their greater knowledge about their own perceptions and abilities in comparison to an average 11-16 year old child. Additionally respondents may have not had the same journey in mind for both questions; they may have envisaged the child cycling on pavements as opposed to themselves cycling on the road or the child avoiding busier roads that they would have to use to make their journey.

As stated in Section 4.3.1 the response patterns for the attitudinal statements were found to be non-normal, as such the median is used as the measure of central tendency in this analysis as opposed to the mean. The median responses for each group shown in Table 5.4 indicate that the median values are the same for both questions for non-cyclists. Those that cycled occasionally or frequently provided the same median average scores for the safety of a child. The lack of change in the average for non-cyclists, combined with the parity within those that cycle at least occasionally, may suggest that the question about the child cycling provides a better representation of the local cycling environment since, while it cannot be completely objective, it reduces the influence of the individual's perceptions of their own abilities.

	Cycling Levels			
	Non-cyclists	Occasional cyclists	Regular cyclists	Kruskal Wallis p-value
Median Safety (self)	3	6	7	<0.001
Median Safety (child)	3	5	5	<0.001
Mann Whitney Test p-value	0.48	<0.001	<0.001	

TABLE 5.4: Summary statistics for perception of safety questions Safety (self) - trip would be safe for yourself Safety (child) - trip would be safe for a child

As introduced earlier, a second question was asked which covered the elements of a cycling journey which do not fall into safety. The aim of this question was to combine the remaining concepts from the CROW guidance (CROW, 2007). It was felt that asking individual questions for each area may lead to fatigue and be unnecessarily complicated for non-cyclists. The wording chosen was to ask respondents how confident they were that the journey would be "comfortable and simple to make".

Although, this wording does attempt to address two elements in the same question, it was felt that this was the best way to elicit responses about the general 'usability' of the local cycling environment. While the use of double-barrelled questions is generally discouraged (Bryman, 2016) previous discussions of the use of double-barrelled questions have argued that they can be acceptable when considering the length of the questionnaire when it is felt that the two concepts are sufficiently similar (Forth et al., 2010). There could be a sense that, in this context, uncomfortable journeys are unlikely to be simple and high level of agreement may indicate that the respondent was agreeing with both characteristics. A low level of agreement might be expected where a respondent is intending either indicate disagreement with both, or to report a low level of agreement based on one of the characteristics without necessarily disagreeing with both. If the respondent found the question confusing, or dealt with agreeing with one characteristic while disagreeing with the other by reporting a moderated disagreement based on both, a neutral response would be expected. Respondents who responded 5 to these questions could using it as a neutral response because the double-barrelled wording. However the proportion of '5' responses is not higher for these questions than it is for the questions dealing with safety only. The comparisons are:

- 10.6% for Safe (Self) compared to 11.0% Comfortable and Simple (Self)
- 15.2% Safe (Child) compared to 15.4% Comfortable and Simple (Child)

The spread of responses from upper band and lower band respondents is not out of line with other statements dealing with similar topics within the questionnaire.

As with the question regarding safety, the same wording was used with separate questions for the respondent and an 11-16 year old child riding alone. The results are summarised in Tables 5.5 and 5.6 Figures 5.3 and 5.4.

Confidence	Cycling Frequency			Total
	Non-cyclists	Occasional cyclists	Frequent cyclists	
0	29.4%	5.3%	3.4%	15.1%
1	6.4%	4.1%	2.3%	4.5%
2	9.2%	6.7%	3.1%	6.5%
3	7.2%	9%	4.8%	6.7%
4	8%	9.1%	5%	7.2%
5	11.4%	12.2%	9.8%	11%
6	6.5%	11.5%	9.1%	8.5%
7	7%	14.7%	15.7%	11.7%
8	7.6%	13.2%	18.8%	12.7%
9	3%	6.7%	13.1%	7.4%
10	4.4%	7.5%	14.9%	8.8%
Total n	**1647**	**825**	**1335**	**3807**

TABLE 5.5: Confidence a journey in the local area would be comfortable and simple to make - by cycling level

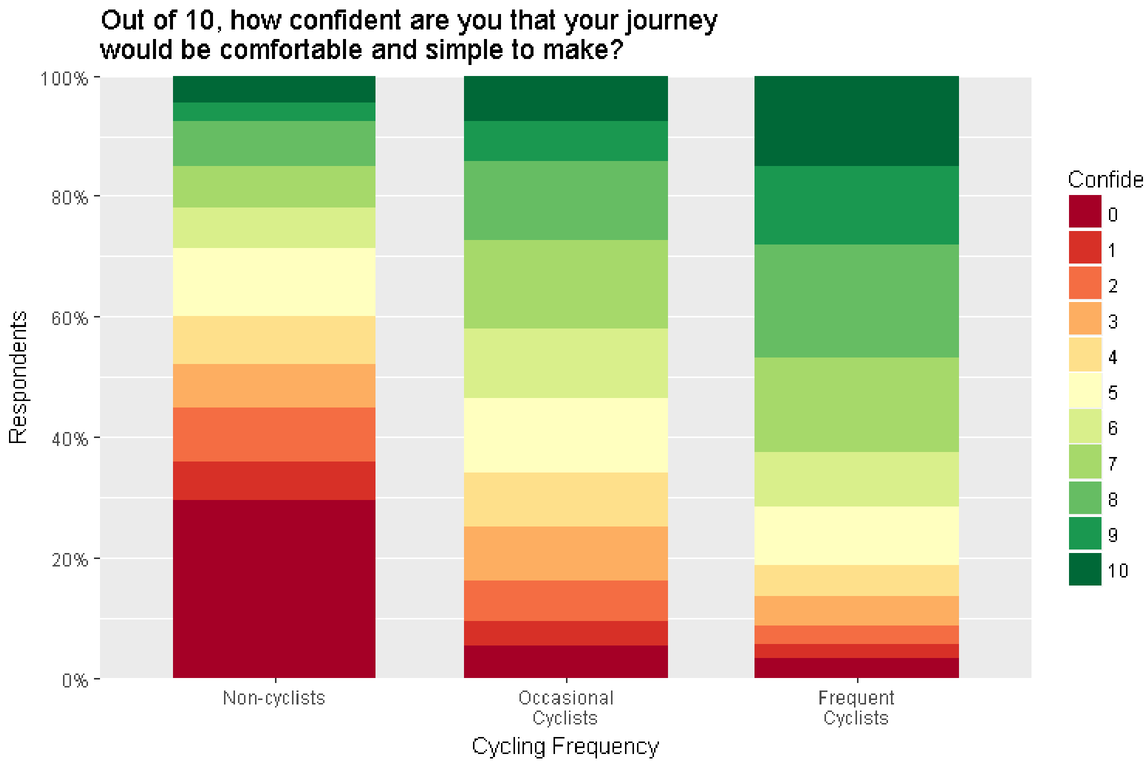


FIGURE 5.3: Confidence a journey in the local area would be comfortable and simple to make - by cycling level

Confidence	Cycling Frequency			Total
	Non-cyclists	Occasional cyclists	Frequent cyclists	
0	21.5%	9.1%	7.5%	13.9%
1	7.5%	6.5%	3.9%	6%
2	8.4%	9.5%	5.9%	7.8%
3	10%	9.7%	6.2%	8.6%
4	8.6%	9.7%	7.6%	8.5%
5	14.8%	17.7%	14.8%	15.4%
6	8.2%	9.2%	14.4%	10.6%
7	7.3%	12.1%	14.2%	10.8%
8	8.2%	9.3%	12.2%	9.9%
9	2.5%	3.8%	6.7%	4.3%
10	2.9%	3.4%	6.5%	4.3%
Total n	**1647**	**825**	**1335**	**3807**

TABLE 5.6: Confidence a journey in the local area would be comfortable and simple for 11-16 year old child - by cycling level

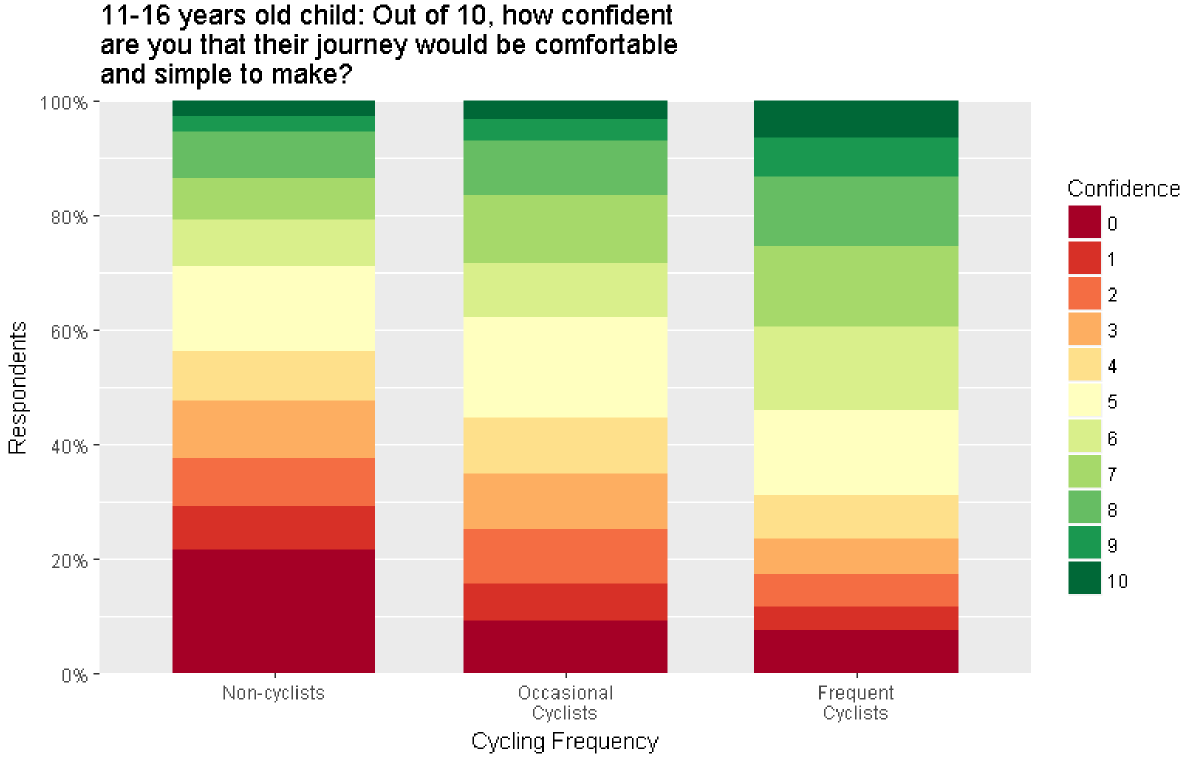


FIGURE 5.4: Confidence a journey in the local area would be comfortable and simple for 11-16 year old child - by cycling level

	Cycling Levels			
	Non-cyclists	Occasional cyclists	Regular cyclists	Kruskal Wallis p-value
Median Comfort and Simplicity (Self)	3	6	7	<0.001
Median Comfort and Simplicity (Child)	5	5	6	<0.001
Mann Whitney Test p-value	0.003	<0.001	<0.001	

TABLE 5.7: Summary statistics for 'comfortable and simple' questions Comfort and Simplicity (Self) - trip would be comfortable and simple for yourself Comfort and Simplicity (Child) - trip would be comfortable and simple for a child

Table Summary Statistics Comfortable Table and Figures 5.3 and 5.4 show that response patterns for these questions were similar to those regarding safety, especially for the question regarding the respondent themselves. However, there are larger differences for those questions when respondents are considering a child. These responses show that for each group the average response is significantly higher for comfort and simplicity than for safety (Non-cyclists $p=0.04$, Occasional, $p = 0.02$, Frequent $p = 0.01$). The differences between the responses when the respondent is thinking about themselves are not significantly different. This indicates that respondents feel safety for child cyclists is greater than for themselves and, combined with the greater similarity between responses for cyclists and non-cyclists, this approach may provide a more accurate estimate of the true perceived safety level.

Differences by gender: As found in the literature review several studies have found that females have lower perceptions of safety than males (Aldred, Elliott et al., 2016), and that they consider that this issue is more important. The differences between genders were tested by performing Mann Whitney tests on the responses to these questions to compare males and female respondents; separate tests were carried out for each of the groups based on cycling frequency. The results of this comparison are summarised in Table 5.8.

	Cycling Levels		
	Frequent cyclists	Occasional cyclists	Non-cyclists
Safety (self) - Male	8	6	4
Safety (self) - Female	7	5	2
Mann Whitney Test p-value	<0.001	<0.001	<0.001
Comfort and Simplicity (self) - Male	8	6	4
Comfort and Simplicity (self) - Female	7	5	2
Mann Whitney Test p-value	<0.001	<0.001	<0.001
Safety (Child) - Male	6	5	4
Safety (Child) - Male	5	4	3
Mann Whitney Test p-value	<0.001	0.02	0.001
Comfort and Simplicity (Child) - Male	6	5	4
Comfort and Simplicity (Child) - Female	5	5	3
Mann Whitney Test p-value	<0.001	0.06	0.002

TABLE 5.8: Summary statistics for perception of the environment – by cycling level and gender Safety (self) - trip would be safe for yourself Safety (Child) - trip would be safe for a child Comfort and Simplicity (Child) - trip would be comfortable and simple for yourself Comfort and Simplicity (Child) - trip would be comfortable and simple for a child

This analysis shows that all but one comparison between male and female respondents shows a significant difference, with the male response higher (more positive) in each situation, both when thinking about themselves and thinking about a child. This finding aligns with the expected pattern found within the literature, with male, Frequent cyclists having the most positive perceptions and female non-cyclists having the least positive perceptions (Aldred, Elliott et al., 2016). The average responses are closer for the questions relating to a child. This may suggest that this is a useful measure which comes closer to their perception of how safe the cycling environment is with less influence from their perceptions of their own cycling ability.

5.3.2 *Perceptions about specific elements of the cycling environment*

The previous section has established the patterns relating to the general questions about the local cycling environment. This section now looks at the statements which were designed to represent specific elements of the cycling environment.

The text of the statements and the results are shown below for each group of statements. It should be considered when interpreting these tables that, due to the phrasing of the questions (for example *"Cycling after dark is more dangerous because it is harder for drivers to see you"*) a statement of agreement represented by a low median value is not always a positive view.

Safety: Seven statements were used which were designed specifically to elicit opinions about elements of the cycling environment which relate to safety. The response pattern for the entire dataset shows that, in general, the respondents had a negative view of each element indicating that the majority of respondents do not feel that on these measures their local area are safe for cycling.

		Median					
No.	Statement Text	♂	♀	F	O	N	All
S29	Cyclists are provided with sufficient protection at roundabouts	5	5	5	5	5	5
S34	Cyclists are protected on roads with fast moving traffic	5	5	5	5	5	5
S36	Car/van drivers give cyclists enough time and space	5	5	5	5	5	5
S41	The residential roads in my area are safe for cycling	3	4	3	3	4	3
S47	Bus/HGV drivers give cyclists enough time and space	5	5	5	5	5	5
S48	Cycling after dark is more dangerous because it is harder for drivers to see you	2	2	2	2	2	2
S49	Cyclists are provided with sufficient protection at junctions and when crossing side roads	4	5	5	5	5	5

TABLE 5.9: Responses to statements relating to safety - Median values are shown for data broken down by gender (♂and ♀) and level of cycling (F= frequent, O = occasional, N - non-cyclist) as a well as for the whole dataset (All). Significant differences are discussed in the text.

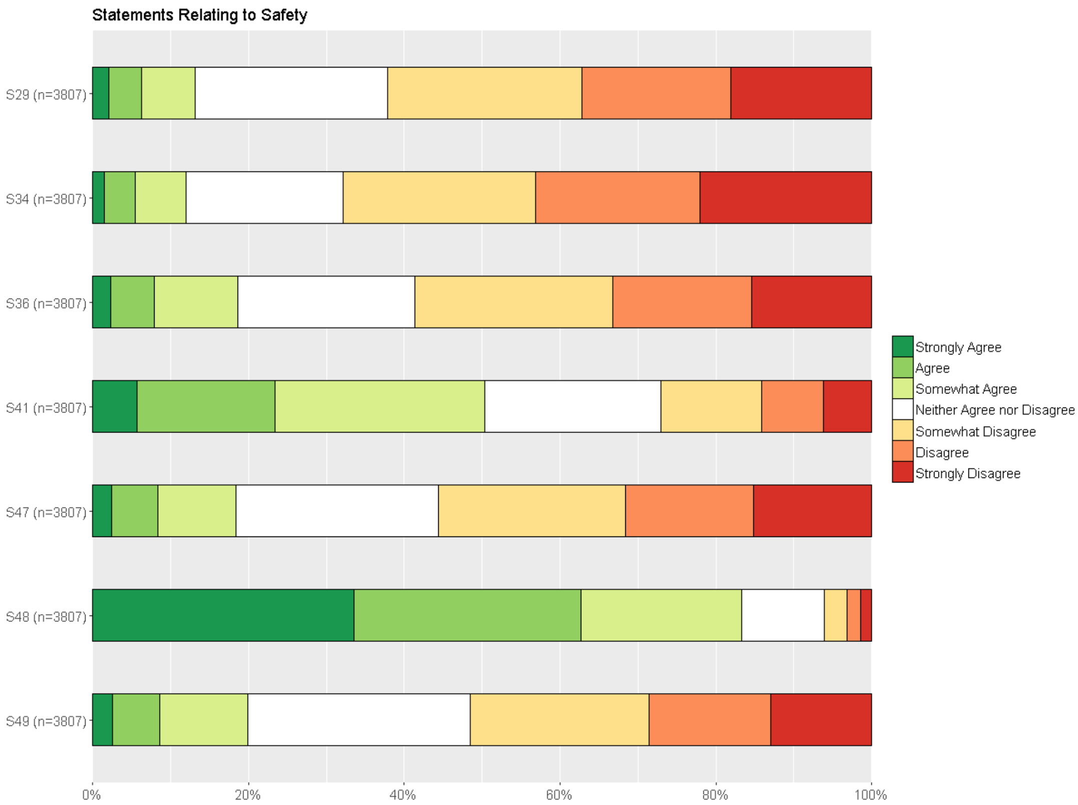


FIGURE 5.5: Pattern of Responses for Statements Relating to Safety (full data set)

- **'cyclists are protected on roads with fast moving traffic'**

The statement which elicited the lowest level of agreement was S34 with 68% of respondents disagreeing with this statement. Further analysis by cycling level and gender demonstrates a high level of agreement between the groups with the median for each gender subgroup being 5 (Somewhat Disagree). This indicates that, in general, both men and women across all levels of cycling feel that cyclists are not protected from moving traffic. Despite this agreement with the median responses, differences can be seen when the results are broken down further. 19% of male frequent cyclists agree that cyclists are protected compared to 6% of female frequent cyclists, a Mann-Whitney test shows that there is a significant difference between these two groups ($p = 0.04$).

- **'cyclists are provided with sufficient protection at roundabouts'**

Statement S29 also produced a low level of agreement. This question was worded to focus attention on roundabouts since, whereas cyclists can be protected from fast traffic in many ways with different levels of segregation from motor traffic, roundabouts can be a particular safety issue for cyclists due to the differential in speed and direction when a vehicle is attempting to leave a roundabout (Urban Movement & Phil Jones Associates and Transport for London, 2014). Again the median response for each subgroup is 5 (somewhat disagree) indicating a general sentiment that cyclists are not protected sufficiently at roundabouts. Combined with a similar pattern of responses for the question regarding fast traffic, this suggests that the majority of the sample feel that cycling is unsafe because of the potential for collisions with motor vehicles at junctions and on major roads (which have fast moving traffic). The more mixed response to the statement regarding the safety residential streets, which is discussed later, also supports this.

- **'Car/van drivers give cyclists enough time and space'**
- **'Bus/HGV drivers give cyclists enough time and space'**

Two statements (S36 and S47) relate to the behaviour of road users and the impact on cyclist safety and are discussed together, this division was used based on the size of the vehicles and reflected how participants within the focus groups used at the development stage talked about vehicles which suggested a greater concern about large vehicles. Again these responses show that cyclists and non-cyclists broadly agree that cyclists are not provided sufficient time and space on the roads by the drivers of motor vehicles. As expected, there are slight differences between the genders. Interestingly the differences are greater when respondents were asked about bus/HGV drivers rather than car/van drivers, with male respondents less likely to feel that car drivers give cyclists enough time and space than bus/HGV drivers whereas the response patterns for female cyclists are more similar for the two statements. This may be related to the HGVs being disproportionately likely to be involved in the death of cyclists (Department for Transport, 2014a) and particularly female cyclists (Frings, Rose and Ridley, 2012) when the cyclist is overtaking the Heavy Goods Vehicle (HGV) on the nearside.

- **'cyclists are given sufficient protection at junctions and when crossing side roads'**

As demonstrated in Figure 5.5 the majority of respondents disagreed with this statement (S49). When the dataset is looked at as a whole there is a higher proportion of neutral responses to this statement. As may be expected for a narrower question such as this, this is particularly evident within the non-cyclist group, with 34% of non-cyclists reporting that they neither agreed nor disagreed with the statement compared to 22% of regular cyclists. The median response for each group is 5 (somewhat disagree) for all groups except Frequent Cyclists. The Mann-Whitney probabilities for gender to gender comparisons were:

- Frequent p = 0.004,
- Occasional p <0.001,
- Non-cyclist p = 0.02.

A Conover test showed that Frequent cyclists were different to occasional and non-cyclists (p<0.001 for both cases) but occasional and non-cyclists were not significantly different (p=0.16).

- **'The residential roads in my area are safe for cycling'**

The responses to the statement S41 show a significant shift in comparison to those discussed so far, with 50% of respondents agreeing that this was the case in their local area. The breakdown by cycling level and gender finds that there are greater differences between the cycling levels (Conover test p <0.001 in all cases). With the median for occasional cyclists and frequent cyclists at 3 (Somewhat agree), this is the only question within this section for which the median average response for any of the groups indicates a positive response. When contrasted with the questions around cyclists being protected from fast traffic and at roundabouts, this suggests that people's main concerns around safety stem from the potentially dangerous interactions on major roads. Also, in contrast to the questions regarding fast traffic and junctions, there is no significant difference between male and female cyclists. The Mann-Whitney probabilities for these comparisons were: Frequent p = 0.34, Occasional p = 0.5.

- **'Cycling after dark is more dangerous because it is harder for drivers to see you'**

The final statement in the safety group (S48) received the most uniform response, with 83% agreeing to this statement. While in many ways this may seem a common sense statement, it is an important aspect with many everyday journeys taking place after dark, particularly in winter months. It also indicates that these respondents feel that cycling is safer during the daylight hours, potentially indicating the importance of issues such as street lighting or high visibility cycle clothing. This is likely to be more relevant to utility rather than leisure cycling as commuting trips in winter are likely to require cycling after dark.

When broken down by cycling level and gender there is little difference between the cycling levels, especially for female cyclists. However, in line with most of the statements in this section, the response from female respondents is slightly less positive, this difference was significant for frequent and non-cyclists (Mann-Whitney: Frequent $p = 0.01$, Non-cyclist $p = 0.03$) but not for occasional cyclists ($p = 0.08$).

Coherence and Directness: Six statements were used to elicit responses on these topics. The text of the statements and the results are shown in Table 5.10 and Figure 5.6.

While, within the CROW design guidance coherence and directness elements are regarded separately these elements have a similar outcome within the experience of the cyclist – a network of routes which is easy to use and makes journeys by bike a convenient option (Welleman, Ministry of Transport Public Works and Water Management and Concorde Vertalingen BV, 1999; Ligtermoet, 2006). Thus the questions are presented here together.

While coherence and directness were not addressed directly within the wording, these statements were designed to capture the overall concepts. The directness of routes is also addressed through the questions on convenience compared to other modes, which are presented later.

		Median					
No.	Statement Text		♀	F	O	N	All
S30	Cycling journeys in my area are stop-start because cyclists are not given right of way	4	4	3	4	4	4
S31	It is clear where people are allowed to cycle and where they are not	4	4	4	4	4	4
S32	The cycle routes in my area are well joined up	4	4	4	4	4	4
S33	There are lots of cycle routes where I live	4	4	4	4	4	4
S35	It is easy to find and follow a suitable route when cycling somewhere for the first time	4	4	4	4	4	4
S38	The cycle routes in my area protect cyclists from parked cars and opening car doors	4	4	4	4	4	4

TABLE 5.10: Responses to statements relating to 'coherence and directness' Median values are shown for data broken down by gender (♂and ♀) and level of cycling (F= frequent, O = occasional, N - non-cyclist) as a well as for the whole dataset (All). Significant differences are discussed in the text

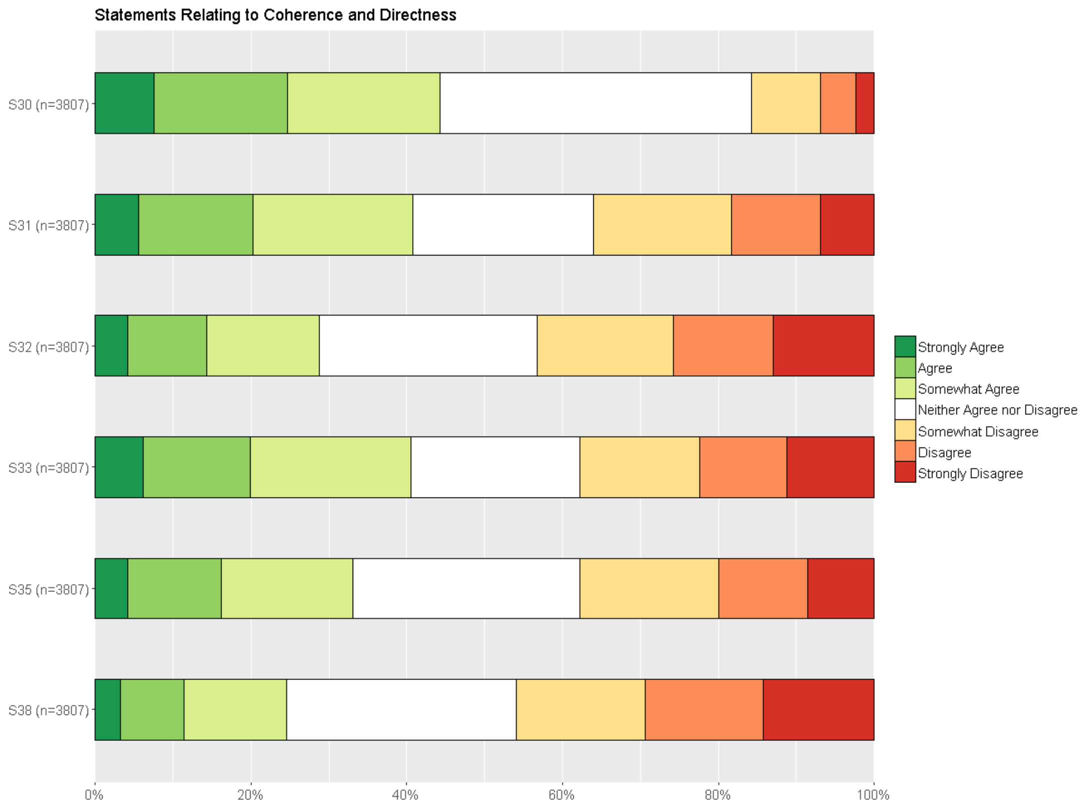


FIGURE 5.6: Pattern of Responses for Statements Relating to Coherence and Directness (full data set)

These response patterns show a more balanced response than those relating to safety, with most statements eliciting a degree of both agreement and disagreement. This suggests that the coherence and directness of the existing routes is perceived more positively than is safety. This aligns with the analysis of the questions relating to the confidence that a journey made in the local area would be 'safe' and 'comfortable and simple' which also showed less confidence that the journey would be safe.

- **'the cycle routes in my area are well joined up'**

The statement with the lowest level of agreement was S32. This statement was primarily designed to elicit responses about the coherence of the local cycling infrastructure, though well joined up routes are also more likely to provide direct options. This question was included based on previous evidence that cyclists value continuous infrastructure which does not disappear at important points, forcing detours or making the route unclear (Buehler and Dill, 2015). The general response pattern to this statement shows that the majority of this sample does not feel that the cycle routes in their area is well joined up (43.4% negative responses compared with 28.7% positive responses).

Comparison also shows the there are no significant differences between male and female respondents within each cycling level, but a Kruskal-Wallis test returned the result that there may be a difference between the distributions when the data is split on cycling level (p<0.001). Based on this, a Conover test was performed which showed that, while the difference between the frequent and occasional cyclists was not significant, the views of both of these groups were significantly different to those of non-cyclists (p <0.001 in both cases). This may partly be due to the higher number of neutral responses from the non-cyclists (34.3%) though a lower proportion of non-cyclists agreed with this statement than the overall dataset (20.6%).

- **'it is easy to find and follow a suitable route when travelling somewhere for the first time'**

The response to S35 shows that more of the respondents disagree with this statement (37.8%) than agree (33.0%). The median scores for each group based on cycling level and gender indicate that only male, frequent cyclists on average agreed that with this statements. Each of the other groups' responses were neutral. Ease finding a suitable route when cycling somewhere for the first time indicates a cycle network which is intuitive, both in signage and in provided clear and direct routes between locations (Urban Movement & Phil Jones Associates and Transport for London, 2014).

- **'there are lots of cycle routes where I live'**

The average response for each group suggests a neutral response to S33 with the same pattern of a slightly more positive response from male, Frequent cyclists applied here as for many of the other statements. A comparison of differences between groups based on cycling level shows that there were significant differences between each group, with cyclists having the most positive response (Conover test p<0.001 in each case). While the infrastructure will play a role in this perception, it is also likely that the confidence and experience of the cyclists will lead to a more positive perception of this issue. For instance, as male cyclists show a less strong preference for segregated infrastructure (Aldred, Elliott et al., 2016) they may find routes easier to find as their threshold for a 'suitable' route is lower.

This is the most relevant of the questions within the survey for comparison to the objective measure of the presence of cycling infrastructure as explained in Section 3.2.1. A Spearman's rank correlation test was used to test the correlation between the response to this question and the amount of cycling infrastructure. Using the preferred measure of the length of cycle route/area of postcode district, a weak correlation was found between the two measures (rho=0.22). While this is a relatively weak correlation, it may indicate a small but genuine effect; supporting this interpretation. The correlation is higher for Frequent cyclists (rho=0.23) and weaker for non-cyclists (rho=0.17). Frequent cyclists are more likely to be aware of the cycling routes in their area and thus the higher correlation for this group may be caused by their more accurate knowledge.

- **'It is clear where people are allowed to cycle and where they are not'**

Statement S31 was informed by the focus group work completed during the development stage (Section 3.1) and common advice across the various design guidelines e.g. (Transport for London, 2014). The issue of unclear cycling space can result either from unclear markings or signage, both of which are important elements in creating clear, coherent cycling networks. The responses to this question fit into the common response pattern for questions which do not relate to safety. The median values for non-cyclists and occasional cyclists indicate a neutral response overall with no significant differences between genders, though the median value for male cyclists indicates an average response of 'slightly agree'.

The results from the Conover test indicate that there is no significant differences between non-cyclists and occasional cyclists, but both of these groups are significantly different from Frequent cyclists ($p < 0.001$ in both cases), despite the median responses being largely consistent across groups.

- **'Cycling journeys in my area are stop-start because cyclists are not given right of way'**

The final statement in this section (S30) received a higher proportion of don't know responses than most of the other issues. This is believed to be because it is a more specific question which may rely on experience of making journeys by bike to produce a strong opinion. The higher proportion of neutral responses, likely based on experience, is shown in the much higher proportion from non-cyclists (53% compared to 26% of Frequent cyclists). The high proportion of neutral responses from non-cyclists and occasional cyclists produces an average neutral response. Frequent cyclists have a negative median view (somewhat agree with statement). This suggests that those that do not cycle often are unaware of this issue but it is something with which cyclists are somewhat dissatisfied.

Comfort and Attractiveness: The next series of questions look at aspects of the environment which make it comfortable and attractive. These concepts cover aspects of the environment which may not influence journey time or safety directly, but which contribute to making the journey simpler and easier, such as bike parking at each end of the journey and route maintenance. S20 which may also evoke issues regarding safety is included in this grouping because it was designed to capture the feeling of vulnerability cyclists can feel which was determined to be associated with the general feel of a secure environment common to other statements within 'Comfort and Attractiveness'.

		Median					
No.	Statement Text	♂	♀	F	O	N	All
S20	My friends and family would/do worry about me getting hurt riding a bike	4	3	3	3	3	3
S26	Poor quality surfaces on roads and cycle routes cause problems for cyclists in my area	3	3	3	3	3	3
S27	The cycle routes in my area are well cleared/gritted in winter	4	4	4	4	4	4
S28	The cycle routes in my area are attractive and well kept	4	4	4	4	4	4
S37	Poorly placed street furniture/signs cause obstructions on cycle routes in my local area	4	4	4	4	4	4
S40	You are vulnerable to violent crime when cycling alone after dark	4	3	4	4	3	4
S42	You are vulnerable to verbal abuse when cycling	3	3	3	3	3	3
S43	I have a good space to store a bike at home for day-to-day use	3	3	2	2	4	3
S44	It is easy to securely park your bike when out and about	4	4	4	4	4	4
S45	Cycling in my area is unpleasant due to traffic fumes	4	4	4	4	4	4

TABLE 5.11: Responses to statements relating to 'comfort and attractiveness' - Median values are shown for data broken down by gender (♂and ♀) and level of cycling (F= frequent, O = occasional, N - non-cyclist) as a well as for the whole dataset (All). Significant differences are discussed in the text.

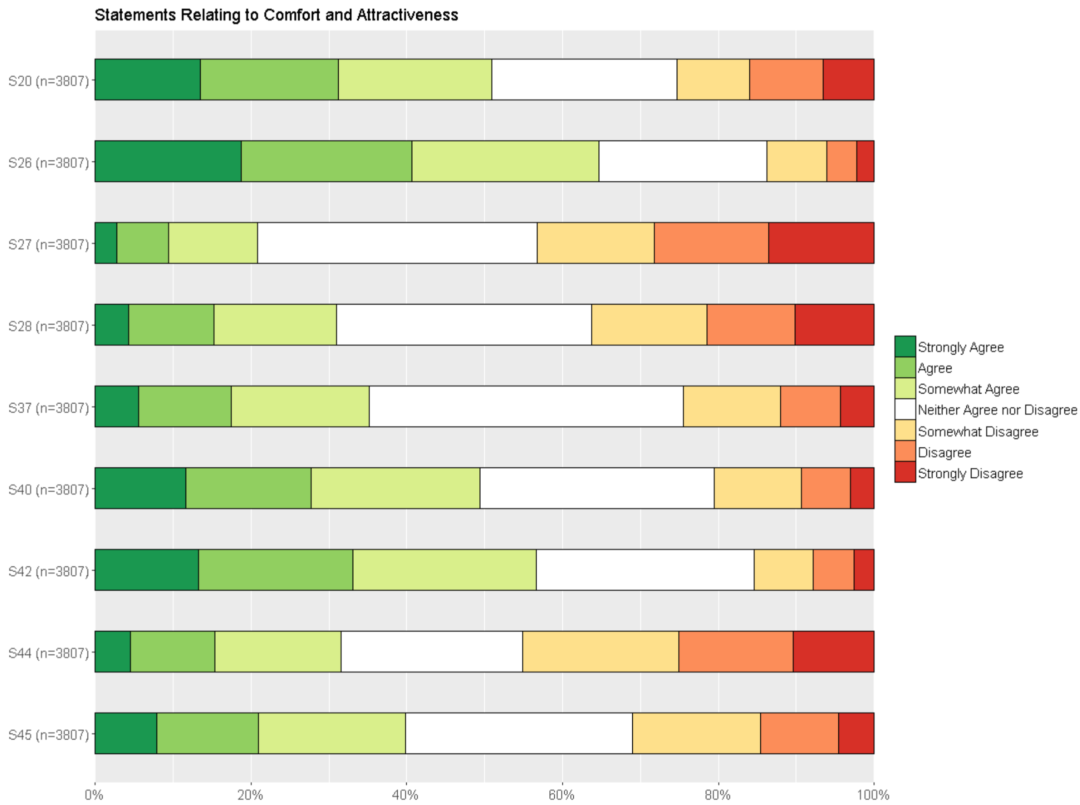


FIGURE 5.7: Pattern of Responses for Statements Relating to Comfort and Attractiveness (full data set)

The overall response to these statements shows a generally negative response. Some issues, such as the issue of poorly placed signs which is included in the LCDS guidance (Transport for London, 2014), has a very high proportion of neutral responses. This is likely to be due to the lack of knowledge on this area among non-cyclists, as with the question about cycling priority, which was included under the statements regarding directness and coherence.

- **'Poor quality surfaces on roads and cycle routes cause problems for cyclists in my area'**

Statement S26 was designed to obtain respondents views on the quality of infrastructure. One of the key aspects of providing good cycling infrastructure is the provision of smooth and level surfaces for cycling – both in construction and through maintenance. This is particularly important for cycling due to the increased level of discomfort felt by cyclists on uneven surfaces (Clayton and Musselwhite, 2013). As cyclists do not only use dedicated infrastructure this statement referred to both roads and cycle routes.

The median average responses for each sub-group consistently indicate an average response of 'somewhat agree' for each group. This shows that there is a general dissatisfaction with the quality of route surfaces. Due to the wording of the question it is not possible to know whether this dissatisfaction is mainly caused by the quality of the cycle route or road surface. Despite the similar average responses, a Conover test found significant differences between regular cyclists and the other groups ($p < 0.001$ in both cases). This could be caused either through greater awareness of the issue among cyclists.

- **'The cycle routes in my area are well cleared/gritted in winter'**

Respondents were asked whether they agreed with the statement (S27) that this aspect is particularly important in maintaining cycling levels across the year (City of Copenhagen, 2011). The pilot study (Section 3.3) which suggested that the gritting of cycle routes in winter was linked to cyclist satisfaction with the environment. The response to this statement in the main survey also fits the pattern for many non-safety related issues with no significant differences between genders. The median response for each group indicates a neutral response overall.

- **'The cycle routes in my area are attractive and well kept'**

Another important issue with maintenance is the providing routes which are attractive and inviting, the same pattern of responses was found for statement S28 though there was a slightly more positive response from Frequent cyclists and a Conover test found differences across each level of frequency ($p < 0.001$ in each case). This may partly be due to a higher proportion of neutral responses from non- cyclists, but could be linked to geography, knowledge or different interpretations of "attractive". The cycle route data available which has been used in comparison to the perceived presence of cycle routes and does not allow for the testing of subjective measures of quality.

- **'Poorly placed street furniture/signs cause obstructions on cycle routes in my local area'**

Respondents were also asked whether they agreed that with this statement. Once more a similar average response was found for this statement, with a neutral response overall, with no significant differences between genders. However, as with the statement regarding stop-start journeys (S30) within the coherence and directness section, there was a large proportion of don't knows (51.5% for non- cyclists).

- **'You are vulnerable to violent crime when cycling alone after dark'**

- **'You are vulnerable to verbal abuse when cycling'**

There were two questions relating to Personal Security (S40 and S42). This issue was reported by a female cyclist within the focus groups which were used at the development stage of this project (Section 3.2) and it is found within the literature as a concern which may affect mode choice (Scheiner and Holz-Rau, 2012). As expected from the literature, there is a large difference in the response patterns of female and male respondents to the statement relating to violent crime with 14.7% of frequent female cyclists strongly agreeing with this statement compared to 5.7% of frequent male cyclists For each level of cycling the average male response is neutral, while the average female response is in agreement with the statement, Kruskal–Wallis tests found significant differences when comparing frequent, occasional and non-cyclists ($p<0.001$ in each case).

On average, all groups presented in Table 5.11 somewhat agreed with the statement regarding verbal abuse, though no significant differences by gender were obvious within any of the levels of cycling.

- **'It is easy to securely park your bike when out and about'**

One statement relating to bicycle storage was included within this group (S44), S43 which focussed on bike storage at home was included under 'Convenience of Cycling'. The median response to the statement for each group presented in Table 5.11 indicates a neutral overall response. The only significant difference between genders within levels of cycling frequency is for frequent cyclists (Mann-Whitney $p = 0.003$) with 49.1% of frequent male cyclists responding positively to this statement compared to 41.7% of frequent female cyclists. A potential reason for the pattern with this question, which was felt to be important within the focus groups, is that), women are more likely to make complicated journeys with heavy shopping or with children (Eyer and Ferreira, 2015). These issues would make parking more difficult.

- **Cycling in my area is unpleasant due to traffic fumes**

There was one statement relating to traffic fumes (S45). Air pollution in urban areas is receiving increasing attention in the media. Despite this increased interest, the response across gender and cycling level groups is neutral with slight but significant differences between cyclists and non-cyclists (Conover test: Non Cyclists >Occasional, $p<0.001$, Non Cyclists>Frequent, $p<0.001$).

5.3.3 *Summary of findings from analysis of statements relating to the cycling environment*

Safety: This analysis of questions related to specific aspect of Safety shows that regarding these individual measures of features of the cycling environment there is broad agreement between those from different cycling levels. Despite this broad agreement, there are slight differences; consistently male cyclists have the most positive perception and female non-cyclists have the least positive perception.

In general the average response to each of these questions showed a slightly negative perception, with the one issue statement which showed a more positive than negative response related to the safety of cycling on residential roads. The similarity of the other responses may suggest that their responses were reflective of their general perception of cycling provision on major roads and that cycling on residential roads was considered separately by respondents. This would suggest that these elements should be regarded as separate constructs within path modelling analysis.

Coherence and Directness: The directness and coherence statements found smaller differences between males and females than the safety related statements. This is consistent with the literature as the main difference within which a common explanation for differences in the strength of preferences for segregated cycling infrastructure is a lower tolerance for risk (Aldred, Elliott et al., 2016). Additionally, within the statements relating to directness and coherence, those which do demonstrate a significant difference between genders may be explained by a different level of tolerance for cycling without 'good' infrastructure.

A further point, which may be a limitation within the path modelling analysis (Chapter 6), is that this analysis reinforces the issue that cyclists have a greater knowledge of the cycling infrastructure in their area and, especially, of the design issues which make cycling risky or inconvenient beyond the broader picture of the general level of cycling provision. This can be seen in the lower levels of correlation between the presence of cycling infrastructure and the perception that there are lots of routes and the higher proportion of don't knows for statements relating to issues such as cycling priority.

Attractiveness: In summary the analysis of the overall responses and the differences across cycling level and gender groups shows that the perceptions of the issues relating to attractiveness and comfort is similar to those issues regarding coherence and directness.

One issue which is highlighted within these questions is that there are particular issues which create barriers for women. An example of this is the issue of vulnerability to violent crime which received a much more negative response from female respondents.

5.4 Soft Factors

5.4.1 *Attitudes towards Cycling*

- **'I feel motivated to cycle/start cycling to improve my fitness'**
- **'I feel motivated to cycle/start cycling because it is good for the environment'**
- **'I feel motivated to cycle/start cycling to save money'**

No.	Statement Text	Median ♂	♀	F	O	N	All
S1	I feel motivated to cycle/start cycling to improve my fitness	3	3	2	3	5	3
S2	I feel motivated to cycle/start cycling because it is good for the environment	4	3	3	3	4	4
S3	I feel motivated to cycle/start cycling to save money	4	4	3	4	5	4
S5	In general, I think successful people drive rather than cycle	4	4	4	4	4	4
S6	It's hard to look fashionable when cycling wearing a helmet	4	4	4	4	4	4
S7	Cycling is something I want to do	3	3	2	3	5	3
S13	Cycling provides people with freedom and independence	3	3	2	3	3	3
S14	The British weather puts me off cycling	3	3	3	3	3	3
S16	Cycling is fun	3	3	2	2	4	3
S21	I'm not the type of person that rides a bike	5	4	6	5	3	5
S23	A large number of cyclists put themselves and others in danger	3	3	3	3	3	3

TABLE 5.12: Responses to statements relating to 'attitudes towards cycling' - Median values are shown for data broken down by gender (♂and ♀) and level of cycling (F= frequent, O = occasional, N - non-cyclist) as a well as for the whole dataset (All). Significant differences are discussed in the text.

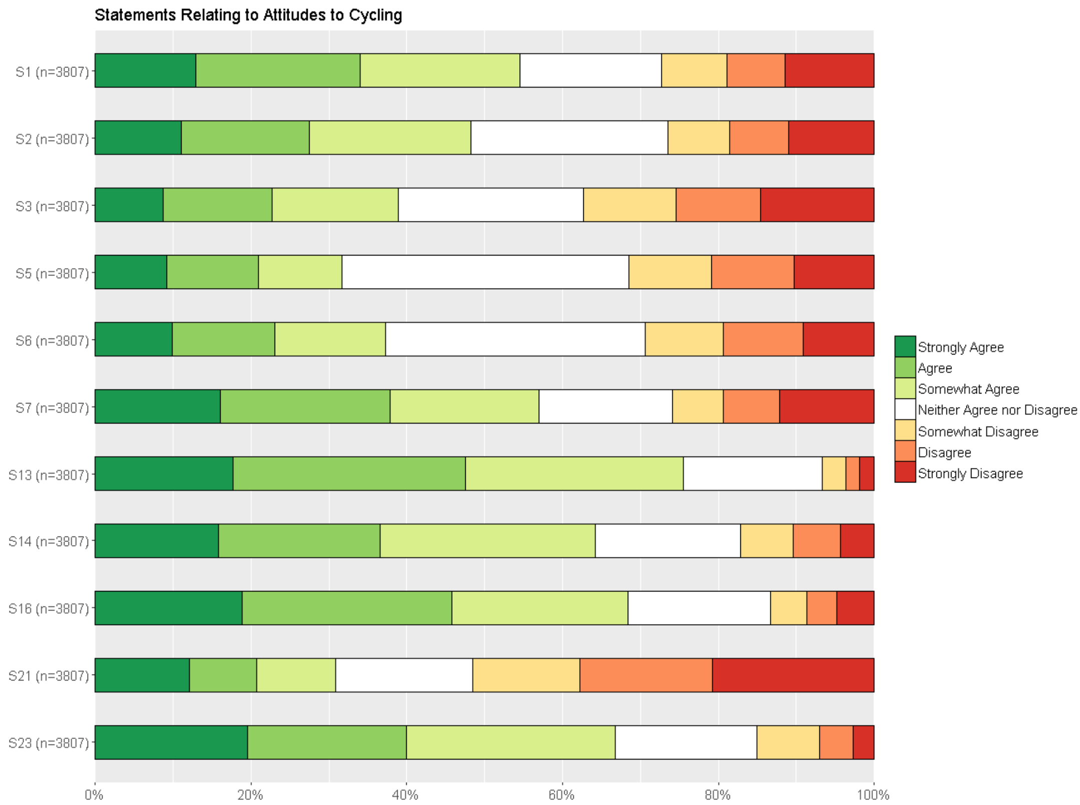


FIGURE 5.8: Pattern of Responses for Statements Relating to Attitudes Towards Cycling (full data set)

Within the statements relating to potential motivations for cycling (S1, S2 and S3) the clearest difference between cyclists and non-cyclists regards the motivation for fitness (Conover test: $p<0.001$ in each case). Frequent cyclists were more likely to strongly agree that they were motivated to cycle for fitness (27.1%) compared with non-cyclists (2.3%). Cyclists were generally more motivated for each of the reasons covered in this statement than non-cyclists. Female cyclists were more likely than male cyclists to be motivated because that is good for the environment (Mann-Whitney: Frequent, $p<0.001$, Occasional, $p<0.001$).

- **'Cycling is something I want to do'**
- **'Cycling provides people with freedom and independence'**
- **'Cycling is fun'**
- **'I'm not the type of person that rides a bike'**

S7, S13, S16 and S21 may be seen to relate to similar themes. Non-cyclists reported generally that they did not want to cycle and also felt that they did not feel like the type of person that rides a bike. This group was more positive regarding the perception that cycling provides people with freedom and independence - aligning with a positive response to this statement from other groups.

As expected there is a strong association between the desire to cycle and the frequency of cycling. Regular cyclists were much more likely to agree or strongly agree with this statement (69.1%) than non-cyclists (10.3%).

The majority of male and female non-cyclists disagreed with this statement however a Mann Whitney test found a significant difference in the response ($p = 0.02$) with males being less likely to strongly disagree with the statement.

The statement 'cycling is fun' found a significant change in responses across each level of cycling with 72.7% of regular cyclists either agreeing or strongly agreeing with this statement compared to just 20.1% of non-cyclists. A similar statement ('I like riding a bike') was found to be the most important predictor of cycling in a study of cycling in 6 US cities (Handy, Xing and Buehler, 2010).

The statement relating to 'freedom and independence' elicited a more positive response from non-cyclists with a majority of non-cyclists agreeing with this statement. One finding from this statement which contrasts with many of the other attitudinal statements is that there is a small but significant difference between male and female frequent cyclists ($p=0.003$) with females slightly more likely to agree with this statement than male cyclists.

- **'In general, I think successful people drive rather than cycle'**
- **'It's hard to look fashionable when cycling wearing a helmet'**

S5 and S6 Were more likely than the other statements in this category to elicit a neutral response from each group, indicating that these are issues which respondents may have not previously thought about, or do not feel strongly about.

Despite the neutral responses to statement 6 which regards wearing a helmet there were significant differences between non-cyclists and cyclists (Conover - $p<0.001$ across all groups) and between male and female respondents at each level (Mann Whitney - $p<0.001$ across all groups). Female respondents within each group were more likely to agree with this statement than male cyclists. This shows a similar, though less pronounced, pattern to the questions regarding showering and changing clothes at work. This highlights again that the necessity to share the road with traffic which increases the physical excursion and the risk of injury is disproportionately a barrier to female cyclists and potential cyclists.

- **'The British weather puts me off cycling'**
- **'A large number of cyclists put themselves and others in danger'**

A commonly discussed barrier to cycling in Great Britain is the weather (S14). Unexpectedly the response to this question shows a broad level of agreement across cycling levels and genders with each group on average 'somewhat agreeing' that they are put off by the weather, this may indicate that while it is a barrier other issues encourage or enable cyclists to overcome this barrier.

While significant differences were found between male and female respondents at all levels of cycling (Mann-Whitney: $p<0.001$ in each case) the response of male frequent cyclists is obviously different from the other groups. Compared to 10.5% of female frequent cyclists 16.6% of male frequent cyclists disagreed or strongly disagreed with this statement. This may be associated with the responses to questions relating to showering and clothing which are more likely to be an issue in poor weather.

All groups presented in Table 5.12 tended to agree that many cyclists put themselves and other danger (S23) with the average response 'Somewhat Agree', highlighting the negative perception, even among frequent cyclists.

5.4.2 *Convenience of Cycling*

- **'My day-to-day journeys are too long to cycle'**
- **'It would be easy for me to fit cycling into my home and work routine'**

These statements (S10 and S15) relate to the common barriers to cycling (Pooley, Tight et al., 2011). Interestingly the group most likely to agree that their journeys are too long to cycle are Occasional cyclists. This may relate to their higher participation in leisure cycling and greater keenness to cycle in comparison to non-cyclists, leaving distance as an important remaining barrier.

No.	Statement Text	Median					
		♂	♀	F	O	N	All
S8	I often have to travel with shopping which is heavy	3	2	3	3	3	3
S9	I am unable to cycle due to childcare commitments	7	6	6	6	7	6
S10	My day-to-day journeys are too long to cycle	4	4	4	3	4	4
S12	Cycling is more convenient than driving	4	4	4	4	5	4
S15	It would be easy for me to fit cycling into my home and work routine	4	4	3	4	5	4
S18	Cycling is more convenient than walking	3	4	3	3	4	4
S19	Cycling is more convenient than getting public transport	3	3	2	3	4	3
S39	It is hard to cycle where I live because there are steep hills	4	4	4	4	4	4
S43	I have a good space to store a bike at home for day-to-day use	3	3	2	2	4	3

TABLE 5.13: Responses to statements relating to 'convenience of cycling' - Median values are shown for data broken down by gender (♂and ♀) and level of cycling (F= frequent, O = occasional, N - non-cyclist) as a well as for the whole dataset (All). Significant differences are discussed in the text.

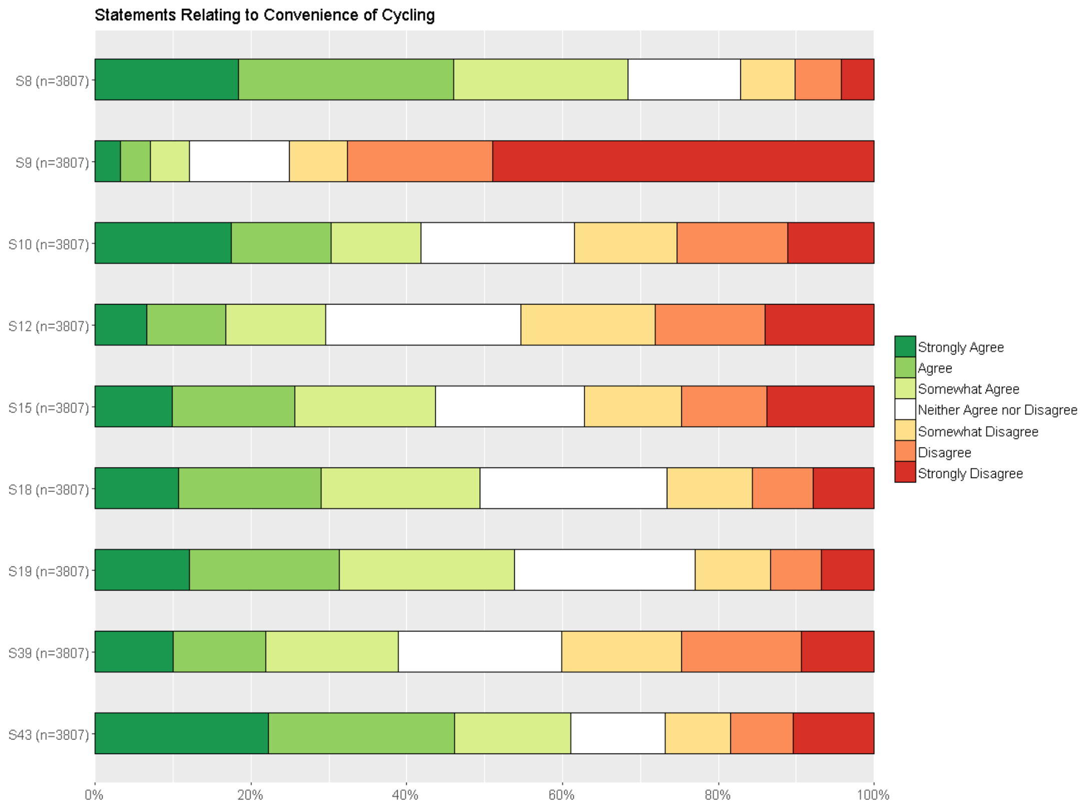


FIGURE 5.9: Pattern of Responses for Statements Relating to Convenience of Cycling (full data set)

In response to S15, frequent cyclists were the most likely to agree that this would be easy. Looking into the non-cyclist group in more detail at non-cyclists female respondents were significantly more likely to disagree with this statement than male non-cyclists (Mann Whitney: p = 0.006).

- **'I often have to travel with shopping which is heavy'**
- **'I am unable to cycle due to childcare commitments'**

These statements (S8 and S9) covered some of the issues which make journeys of a cyclable length easier to make by car. Female respondents across each level of cycling were more likely to agree that they had to travel with shopping which was heavy (Mann-Whitney: p<0.001 in each case), and that they were unable to cycle due to childcare than males, this difference was only significant for non-cyclists (Mann-Whitney p<0.001).

- **'Cycling is more convenient than driving'**
- **'Cycling is more convenient than walking'**

- **'Cycling is more convenient than getting public transport'**

S12, S18 and S19 relate directly to the comparison of cycling to other modes. No group had a large proportion of respondents which agreed that cycling was more convenient than the car.

Respondents were more likely to agree that cycling was convenient compared to public transport and walking with the median of 2 for the statement regarding public transport, frequent cyclists have a positive view of cycling in this regard with significant differences being found between each level of cycling (Conover: $p < 0.001$ in each case).

Alongside the travel behaviour analysis presented in Chapter 4, which showed that 41% of Upper Band travelled 'at least once a day' as a car driver compared to 38% of Lower band respondents, this suggests that many of those within this group may not be replacing their car journeys with bike trips but instead making additional cycle trips or, potentially, replacing public transport journeys as they find cycling a more convenient option (Gatersleben and Appleton, 2007).

There was a range of responses for the statement regarding steep hills (S39), this may reflect the geographical distribution of respondents.

- **'I have a good space to store a bike at home for day-to-day use'**

Within the focus groups bike storage at home and at the end of journeys were seen to be big barriers to making everyday journeys by bike, as summarised in Section 3.1. The responses to the statement relating to bike storage (S43) at home found among the largest differences between non-cyclists and cyclists within the questionnaire. While the average response for non-cyclists is neutral, there is a spread of responses across the scale. On the other hand, there is a very response from frequent cyclists, with 62% agreeing or strongly agreeing with this statement. Respondents were not asked about their type of house in the survey so this issue cannot be tested.

5.4.3 *Subjective Norm*

- **'Many people I know cycle'**
- **'I was encouraged to cycle when I was a child'**

For Statement 4 there is a significant difference between each level of cycling (Conover: $p<0.001$ in each case). For this statement there were no significant differences here between male and female respondents for any level of cycling though the difference within Frequent cyclists was closer to significance (Mann- Whitney: Frequent p = 0.05, Occasional p = 0.88, Non-cyclist p = 0.41). Looked at alongside S21, this suggests a potential barrier for women as female respondents are no less likely know cyclists but less likely to think they are the type of person that rides a bike. This relates to (Gatersleben and Appleton, 2007) who found that women that don't cycle often see cycling as "something that other people do".

There was general agreement from all groups that they were encouraged to cycle as children, though as with some other statements the main significant difference when looking in more detail is that female non-cyclists were significantly less likely to report that they felt encouraged to cycle compared with male non-cyclists (Mann-Whitney: p = 0.001) and stand out from other groups with a median response of 'Somewhat Agree' in comparison to 'Agree' for each of the other groups.

- **My friends would approve if I rode a bike/do approve that I ride a bike**
- **My family would approve if I rode a bike/do approve that I ride a bike**
- **My colleagues or coursemates would approve if I cycled/do approve that I cycle**

These statements (S24, S25 and W7) were generally positive responded to. Indicating a feeling of general approval. Frequent cyclists were significantly more likely to feel those close to them approved of them cycling than non-cyclists were of them starting to cycle, suggesting that greater approval could help to encourage or maintain this behaviour.

		Median					
No.	Statement Text	♂	♀	F	O	N	All
S4	Many people I know cycle	4	4	3	4	5	4
S22	I was encouraged to cycle when I was a child	2	2	2	2	2	2

TABLE 5.14: Responses to statements relating to 'subjective norms' (full dataset) - Median values are shown for data broken down by gender (♂and ♀) and level of cycling (F= frequent, O = occasional, N - non-cyclist) as a well as for the whole dataset (All). Significant differences are discussed in the text.

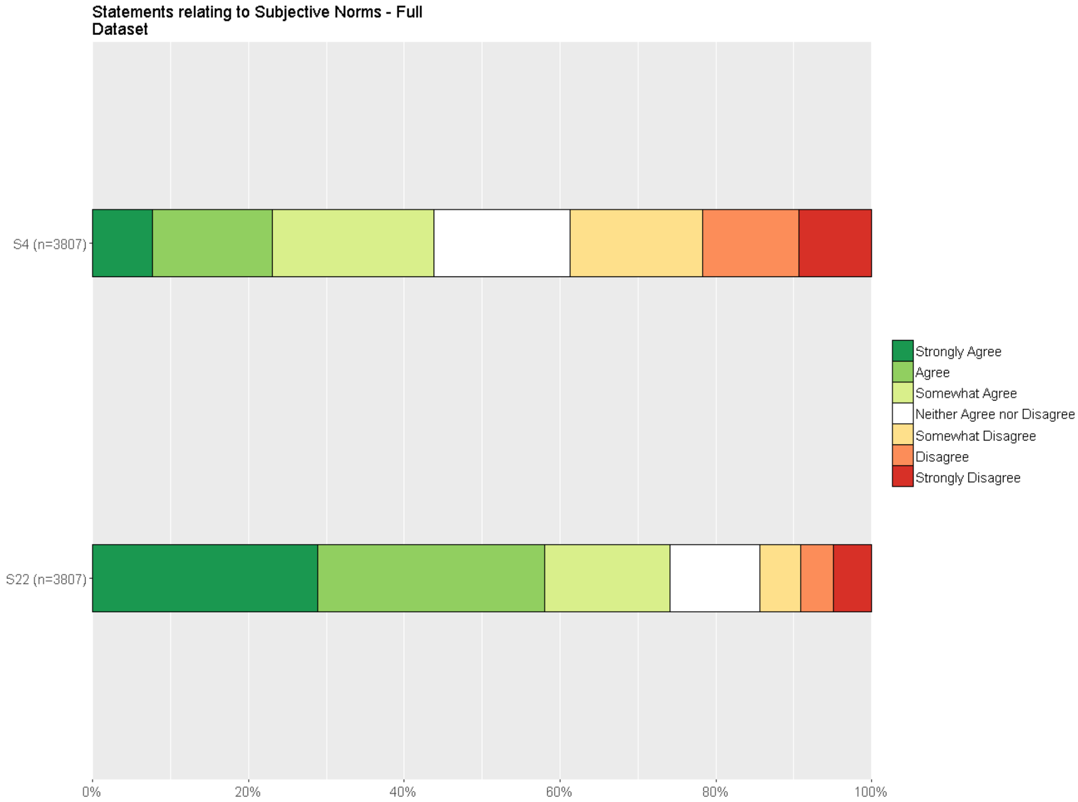


FIGURE 5.10: Pattern of Responses for Statements Relating to Subjective Norms (full dataset)

		Median					
No.	Statement Text	♂	♀	F	O	N	All
S24	My friends would approve if I rode a bike/do approve that I ride a bike	3	4	2	3	4	3
S25	My family would approve if I rode a bike/do approve that I ride a bike	3	3	2	3	4	3
W7	My colleagues or coursemates would approve if I cycled/do approve that I cycle	3	3	2	3	4	3

TABLE 5.15: Responses to statements relating to 'subjective norms' (Second Wave Only) - Median values are shown for data broken down by gender (♂and ♀) and level of cycling (F= frequent, O = occasional, N - non-cyclist) as a well as for the whole dataset (All). Significant differences are discussed in the text.

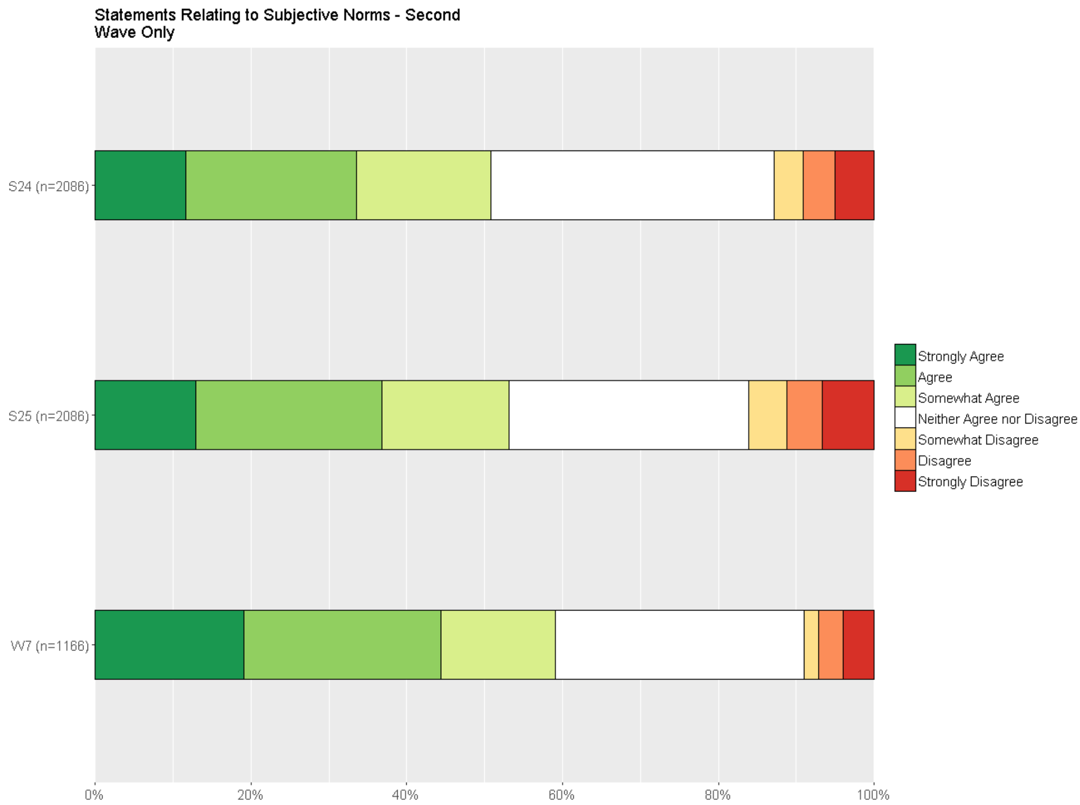


FIGURE 5.11: Pattern of Responses for Statements Relating to Subjective Norms (Second Wave Only)

5.4.4 *Perceived Behavioural Control*

The clearest message from this set of statements is the low level of agreement that respondents felt confident sharing the road with traffic. Even within frequent cyclists more cyclists disagreed or strongly disagreed (29.5%) than agreed or strongly agreed (12.5%). The level of agreement is significantly higher than for frequent cyclists than occasional or non-cyclists (Conover test: $p<0.001$ in each case) and for males than females across each level of cycling (Mann-Whitney: $p<0.001$ in each case)

A large difference can be seen in confidence making minor repairs to a bicycle between male and female respondents, when gender differences within the levels of cycling are analysed this difference is apparent within each cycling level (Conover: $p<0.001$ in each case).

Physical fitness appears to be a barrier to some with 27.5% of non-cyclists disagreeing or strongly disagreeing that they would be fit enough to cycle regularly.

		Median					
No.	Statement Text	♂	♀	F	O	N	All
S11	I am physically fit enough to cycle regularly	2	3	2	2	4	3
S17	I would be confident making minor repairs to a bicycle (e g a puncture)	2	5	2	3	4	3
S46	I am confident sharing the road with traffic when cycling	4	5	3	5	5	5

TABLE 5.16: Responses to statements Relating to 'perceived behavioural control' - Median values are shown for data broken down by gender (♂and ♀) and level of cycling (F= frequent, O = occasional, N - non-cyclist) as a well as for the whole dataset (All). Significant differences are discussed in the text.

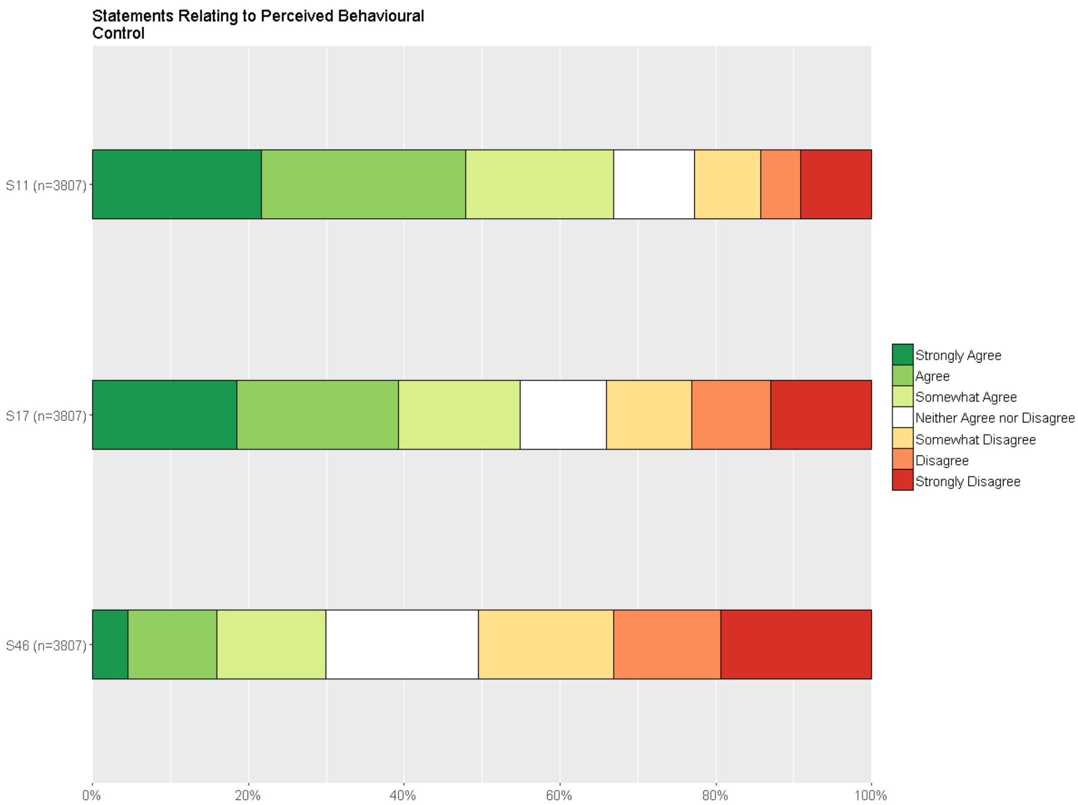


FIGURE 5.12: Pattern of Responses for Statements Relating to Perceived Behavioural Control (full dataset)

5.4.5 *Attitudes Towards Cars*

The responses to these statements showed similar response patterns across the groups based on cycling frequency and gender shown in Table 5.17.

Large proportions of all groups agreed that they preferred making journeys by car, though frequent cyclists were less likely to agree with this statement with only 41.6% agreeing or strongly agreeing to this statement compared to 63.2% of non-cyclists.

Another difference apparent within this set of statements is that non-cyclists were more likely to agree that they were not interested in reducing their car use compared to frequent cyclists, non-cyclists were also less likely to agree that they were motivated to cycle because it is good for the environment suggesting that appealing to these extrinsic reasons to change behaviour may not be effective.

Differences were not found between groups for the statements relating to the enjoyment of driving itself.

		Median					
No.	Statement Text	♂	♀	F	O	N	All
C1	For most journeys I would rather use the car than any other form of transport	2	2	3	2	2	2
C2	I like to drive just for the fun of it	4	4	4	4	4	4
C3	I am not interested in reducing my car use	4	4	4	4	3	4
C4	Driving gives me a way to express myself	4	4	4	4	4	4

TABLE 5.17: Responses to statements relating to 'attitudes towards cars' - Median values are shown for data broken down by gender (♂and ♀) and level of cycling (F= frequent, O = occasional, N - non-cyclist) as a well as for the whole dataset (All). Significant differences are discussed in the text.

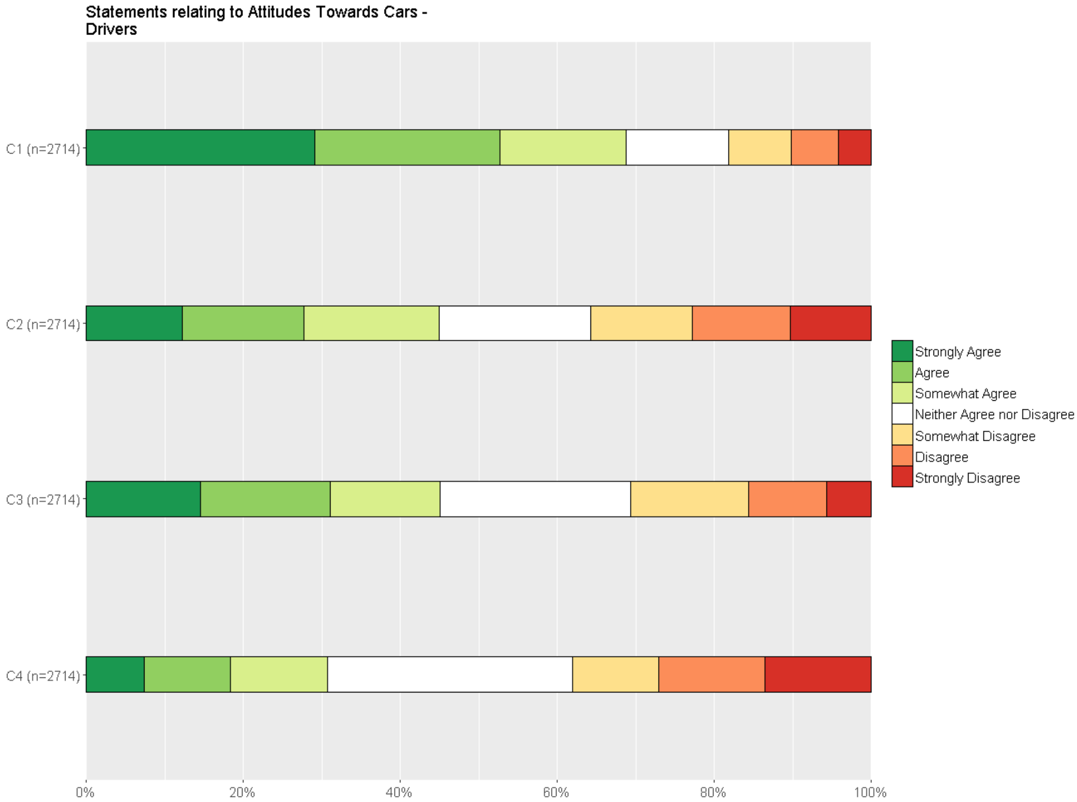


FIGURE 5.13: Pattern of Responses for Statements Relating to Attitudes Towards Cars (respondents that reported driving within the past year)

5.4.6 *Working and the Workplace*

The majority of respondents reported that they did not have to make many journeys during the day and that they did not have to carry heavy equipment which may suggest that their journeys are potentially cyclable under the right circumstances with 46% of those with a commute to a regular place of work also reporting having commutes of under 5 miles.

There was not a strong feeling that workplaces encouraged cycling though most agreed that their workplace had good cycle parking. One issue may be around showers and changing facilities. There was general agreement that respondents would be willing to shower/change at work if the facilities were good but most respondents felt that the facilities were not good. This was a particular issue for female respondents with 50.1% disagreeing or strongly disagreeing that there were good facilities available.

		Median					
No.	Statement Text	♂	♀	F	O	N	All
W1	My place of work/study has good shower/changing facilities	4	6	4	5	6	5
W2	My place of work/study has good bike parking	3	3	3	3	4	3
W3	My place of work/study encourages people to cycle	4	4	4	4	4	4
W4	I would be happy to shower and change clothes at work after cycling into work/study if the facilities were good	3	3	2	3	4	3
W5	I often have to carry equipment for my work which is heavy	5	5	5	5	6	5
W6	I often have to travel during my working day (e g between sites or to visit clients)	5	6	5	6	6	6

TABLE 5.18: Responses to statements relating to 'working and the workplace' - Median values are shown for data broken down by gender (♂and ♀) and level of cycling (F= frequent, O = occasional, N - non-cyclist) as a well as for the whole dataset (All). Significant differences are discussed in the text.

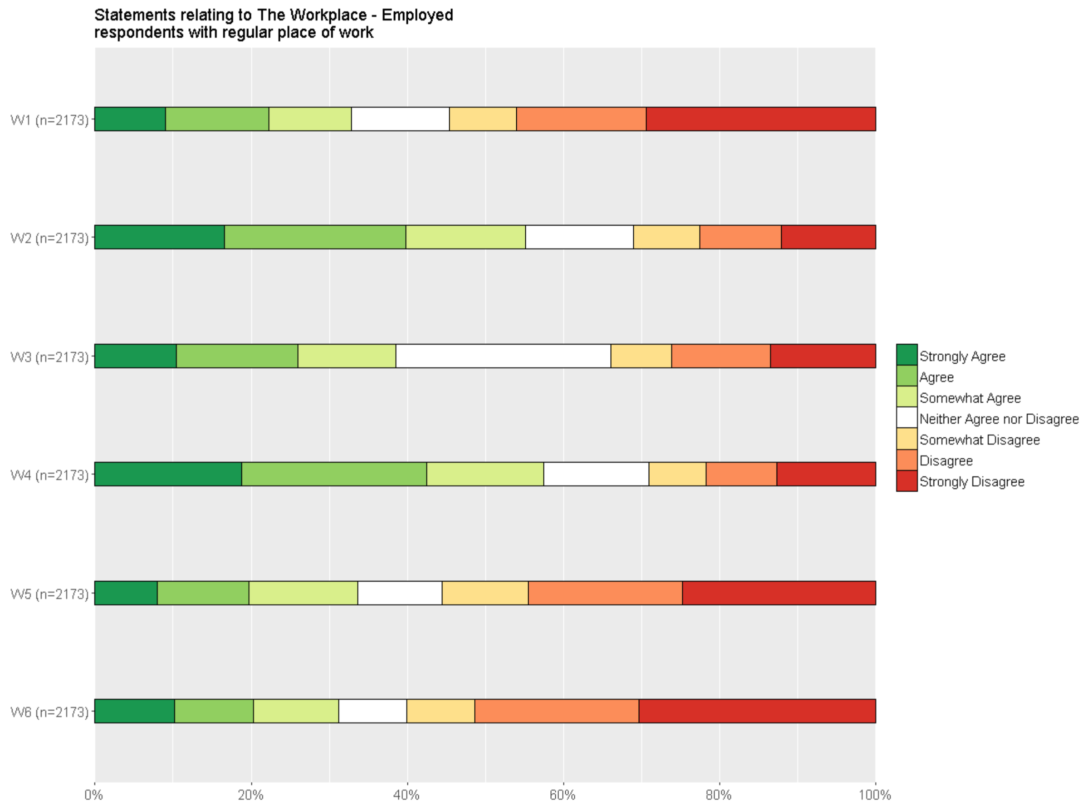


FIGURE 5.14: Pattern of Responses for Statements Relating to Attitudes Towards Cars (employed respondents)

5.5 Summary of findings from attitudinal analysis

The main message which emerges from this analysis is that female respondents have less positive perceptions of the cycling environment, their own abilities and the encouragement they feel from others than male respondents. This pattern is present across each level of cycling.

Additionally non-cyclists generally have less positive views than occasional or frequent cyclists. While this is true for both hard and soft factors, frequent cyclists generally provided positive responses regarding soft factors such as their motivation to cycle to improve their fitness (S1) and finding cycling fun (S16) but all groups provided negative responses regarding hard factors - particularly regarding safety.

An additional pattern which has emerged is that non-cyclists provided a higher proportion of neutral responses for statements regarding specific elements of the cycling environment which may indicate a lower level of knowledge of the issues due to their lower level of exposure to the environment.

The choice of non-parametric methods was based on the results of the normality tests which showed that the data could not be assumed to fit within the normal distribution. While this was not unexpected, it led to the choice of non-parametric methods for the data analysis. Thus, the main findings in Chapter 5 arise from the use of Mann-Whitney, Kruskal-Wallis and Conover tests to establish the presence or absence of differences between subgroups. Nevertheless, non-parametric methods do tend to be less powerful than the parametric counterparts. For that reason, it is possible that the choice of non-parametric methods may have led to type II errors and that potentially interesting results potentially relating to the differences between male and female respondents, that a parametric alternative might have revealed, have remained hidden.

There are three practical approaches to solving this issue based on the common principles of measurement:

- Design a survey that reduces the noise in the data, for example by reducing the number of neutral responses.
- Increase the sample size by reaching more respondents.
- Apply other analysis methodologies (for example, non-frequentist methods)

While acknowledging these limitations these findings contribute to the knowledge base in this area in two main ways, particularly in regards to the comparison of the attitudes and perceptions of males and females to cycling and the cycling environment.

Firstly, much of the previous research has focused mainly on the preferences and experiences of existing cyclists (Aldred, 2013; Willis, Manaugh and El-Geneidy, 2015). Through the collection and analysis of data from a large sample of both cyclists and non-cyclists, this research suggests that the differences between males and females hold across different levels of cycling. This is important as any policies intended to increase levels of utility cycling must necessarily consider the views of those who currently do not cycle.

Secondly, through the analysis of a broad range of qualitative issues (from perceptions of the safety of the cycling environment, workplace facilities and attitudes towards cycling) this research shows that these differences are not restricted to preferences for segregated infrastructure, with female non-cyclists consistently reporting the least positive perceptions of all the issues considered. This highlights the need to address wider societal issues which negatively impact female participation in cycling alongside the installation of cycling infrastructure in order to enable a broader population to cycle.

Chapter 6. PLS-SEM Development and Analysis

The previous two chapters set out the descriptive analysis of the attitudinal statements included within the questionnaire. This:

i Helped identify some differences between population sub-groups.

ii Highlighted that respondents across all levels of cycling agreed that the cycling infrastructure in their local area did not provide adequately for cyclists.

iii Showed that, in general, regular cyclists had more positive attitudes towards cycling.

This chapter builds on these findings, using a Theory-led approach and Structural Equation Modelling.

This chapter:

- Details how the initial model was established using the 2016 data set.
- Details the development and testing.
- Describes the analysis of the model.

The discussion of the model focuses first on the Upper and Lower Band respondents, before moving on to age and gender based subgroups and to response based segmentation.

6.1 Analysis Approach

The model was built using the plspm package in R (Sanchez, 2013) as the outputs available using this package allow for each of necessary criteria to be tested. The results of the initial model and intermediate iterations are now described. This description focuses on the performance measures since any conclusions drawn from the strength of the path coefficients within the structural model would be unreliable if the measurement model is not shown to produce an acceptable validity.

This analysis is performed using data from respondents from both the Upper and Lower bands. Data from respondents with accurately provided English postcodes were used in order to facilitate the use of the measure calculated for cycling infrastructure density. Only respondents from Wave 2 were used to enable the use of the additional statements relating to the Subjective Norm which were added to this version of the survey. These requirements reduced the dataset available for this analysis to 1700 respondents.

6.1.1 *Theory-led Approach*

Rather than using all the statements and exploring differences in response patterns to find issues where attitudes or perceptions differ between subgroups, here a selection of the statements is used to develop a theory-led model which uses a reduced number of the statements to create a model, based on a number of constructs, which works for both datasets. This then allows the testing of the hypothesis that these constructs (alongside a measure of the physical cycling environment) are associated with the *Intention to Cycle*. An advantage of basing the model for this research on theory, rather than specifying a model based on patterns within the data, is that specifying the direction of the relationships within the model is an important stage of structural equation modelling and should be based on established theory to reduce the risk of directionality being misspecified (Hair, Mult et al., 2014).

This selection of constructs was informed by the socio-ecological approach (Madsen, 2013), which looks to combine the individual aspects included within the Theory of Planned behaviour (Ajzen, 1991) with the importance of the physical infrastructure (Handy, Xing and Buehler, 2010). Through the inclusion of objective and subjective measures of the physical infrastructure, this model is intended to provide an insight into the relationship between an individual's perceptions of the infrastructure and their perceptions of the overall journey quality, as well as showing the relative importance of those perceptions compared to other factors (such as the journey convenience and individual factors).

6.2 Model development

Common to SEM techniques, regardless of which estimator is used, is the division of the structural model and the measurement model. The measurement model relates measured variables or indicators to constructs and the structural model relates constructs to one another. In this case the indicators are the individual items included in the questionnaire (the indicator statements listed in Section 4.2) and the constructs are those included in the adapted model based on the socio-ecological approach.

First the measurement model is described, then the structural model development is detailed.

The Measurement Model: The quality of the measurement model is vital in constructing an overall model which is reliable, robust and accurate. To develop a valid model, it is important to consider both the theoretical framework and the validity tests (see Section 3.9). If the model does not line up with the theory then links, which appear to be significant, could lead to erroneous conclusions based on incorrect assumptions of causality. Equally, if the model does not meet the required level of performance for the issues, the wrong items may have been measured, the indicators incorrectly grouped, or there could be errors in the data which also could lead to incorrect conclusions if left unchecked.

The structural model: The structural model represents the links between constructs. The structural model was developed first, based on the socio-ecological approach (Madsen, 2013) which includes the core Theory of Planned Behaviour model (Ajzen, 1991)). In order to simplify the model the relationships between *Perceived Behavioural Control*, *Subjective Norm* and *Attitudes Towards the Behaviour* were removed. The rest of the links in the original model were retained.

The original hypothesised model used the statements included within the questionnaire and grouped them into the same categories as described in Chapter 5. Combining the constructs within the Theory of Planned Behaviour (Ajzen, 1991) and the constructs relating to the physical environment these were based around the CROW design guidance (CROW, 2007) the initial constructs, which are considered in this chapter are:

- Attitudes Towards Cycling
- Convenience of Cycling
- Perceived Behavioural Control
- Subjective Norms
- Safety
- Coherence and Directness
- Comfort and Attractiveness
- Journey Quality
- Intention to Cycle

An initial test of the associations between the indicators was performed to inform any changes to the model which could lead to better performance. In contrast to a factor analysis, which may include the whole range of statements to explore underlying patterns in the data, the indicators which are intended to reflect a single construct were tested together to help identify outliers within each indicator group.

The interpretation is drawn from a graphical output, the 'Circle of Correlations'. This output plots information across two axes, each showing the variable correlations on the first two principal axes with the first two principal components derived from the application of the nonlinear iterative partial least square algorithm for principal component analysis. As this is a measure of correlation the scale for each axis runs from -1 to +1 indicating the strength and direction of the correlation (Sanchez, 2013).

This process was repeated for each of the hypothesised constructs. Each variable is represented by a line with the statement number at the end furthest from the centre of the circle. The length of this line along the x-axis represents the strength of the correlation with the first principal axis and the length of the line along the y-axis represents the strength of the correlation with the second principal axis. When variables group together with strong correlations relating to one of the two axes this suggests that they are correlated and may be related. When one or more variables is not grouped with the others this may suggest that the statement is not related to the others and should be removed or tested within another construct (Sanchez, 2013).

These charts are now presented and discussed for each construct in turn.

6.2.1 *Attitudes Towards Cycling*

Figure 6.1 shows that there are two main statement groups, suggesting that it may be more appropriate to split the overarching attitudes construct into two constructs.

The main group shows strong correlation with the first principal axis. This group appears to relate to Positive Attitudes Towards Cycling, including statements such as S16 *"Cycling is fun"* and S7 *"Cycling is something I want to do"*. S21 *"I'm not the type of person that rides a bike"* is also strongly correlated to the first principal axis, but appears to be slightly less aligned with the rest of the group and is phrased negatively. Within the PLS model development the alignment of this statement with other constructs must be monitored (see Figure 6.1).

The second group shows a weaker level of correlation with the second principal component. The statements which are associated with this group are S5 *"In general, I think successful people drive rather than cycle"*, S6 *"It's hard to look fashionable when cycling wearing a helmet"*, S14 *"The British weather puts me off cycling"*, S23 *"A large number of* *cyclists put themselves and others in danger"*. These statements relate to negative perceptions of cycling and cyclists which appear to be distinct from the *Positive Attitudes*, despite the reordering of the scale for those which were negatively phrased.

Thus, the first run of a hypothesised model was based on the attitudes construct split into two, with *Positive Attitudes* and *Negative Attitudes* grouped separately.

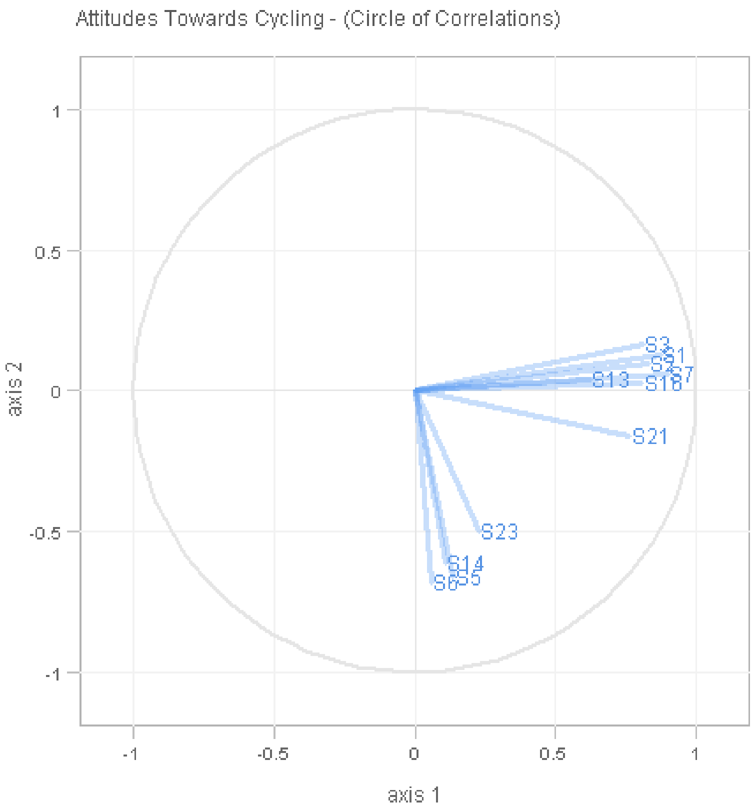


FIGURE 6.1: Circle of Correlations - All Attitudes Statements
S1: 'I feel motivated to cycle/start cycling to improve my fitness'
S2: I feel motivated to cycle/start cycling because it is good for the environment'
S3: 'I feel motivated to cycle/start cycling to save money'
S5: 'In general, I think successful people drive rather than cycle'
S6: 'It's hard to look fashionable when cycling wearing a helmet'
S7: 'Cycling is something I want to do'
S13: 'Cycling provides people with freedom and independence'
S14: 'The British weather puts me off cycling'
S16: 'Cycling is fun'
S21: 'I'm not the type of person that rides a bike'
S23: 'A large number of cyclists put themselves and others in danger'

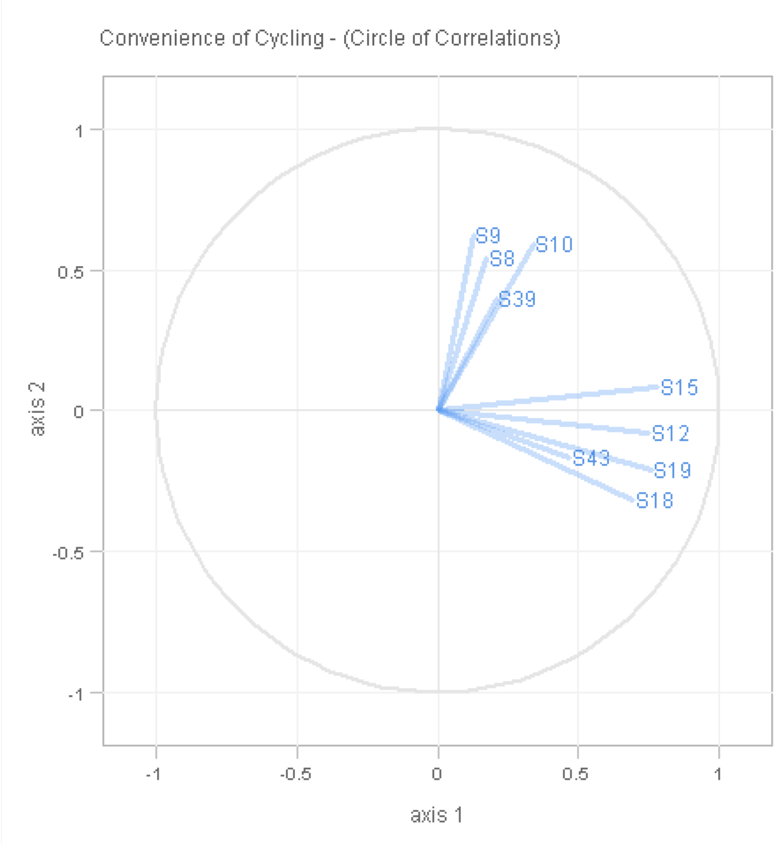


FIGURE 6.2: Circle of Correlations - All Convenience Statements
S8: 'I often have to travel with shopping which is heavy'
S9: 'I am unable to cycle due to childcare commitments'
S10: 'My day-to-day journeys are too long to cycle'
S12: 'Cycling is more convenient than driving'
S15: 'It would be easy for me to fit cycling into my home and work routine'
S18: 'Cycling is more convenient than walking
S19: 'Cycling is more convenient than getting public transport'
S39: 'It is hard to cycle where I live because there are steep hills'
S43: 'I have a good space to store a bike at home for day-to-day use'

Again, two main groups were observed. One of these groups, comprising S12, S15, S18, S19 and S43 can be broadly defined as *Convenience of Cycling* including statements relating to the convenience of cycling compared to other modes of transport and within the daily routine. The second, smaller, group, which includes S8, S9, S10 and S39 can be seen to represent the *Journey Suitability* for cycling including statements which may make journeys more difficult by bike such as hills, childcare and carrying heavy shopping.

These groups were both included within the initial version of the model as *Convenience of Cycling* and *Journey Suitability* respectively.

Statement 43, which relates to the availability of cycle storage at home, appears to be most closely associated to the *Convenience of Cycling* construct, however it does not share the same strength of association as the other statements and so is removed at this stage as it is not similar in content to the other statements and shows a weaker association with the group.

6.2.2 *Perceived Behavioural Control*

One of the core elements in the original Theory of Planned Behaviour is the *Perceived Behavioural Control* construct. In line with previous studies in this area (Passafaro et al., 2014), this construct is focussed around an individual's confidence when cycling, perceived fitness for cycling and confidence repairing a bicycle.

Statements 11, 17 and 46 are included in this construct. As PLS constructs can become biased with less than three indicators (Rigdon, 2016), there is less flexibility to remove indicators based on Circle of Correlations. Nevertheless, producing the Circle of Correlations chart shows that S11, which relates to fitness for everyday cycling, isn't as closely associated as the other two statements.

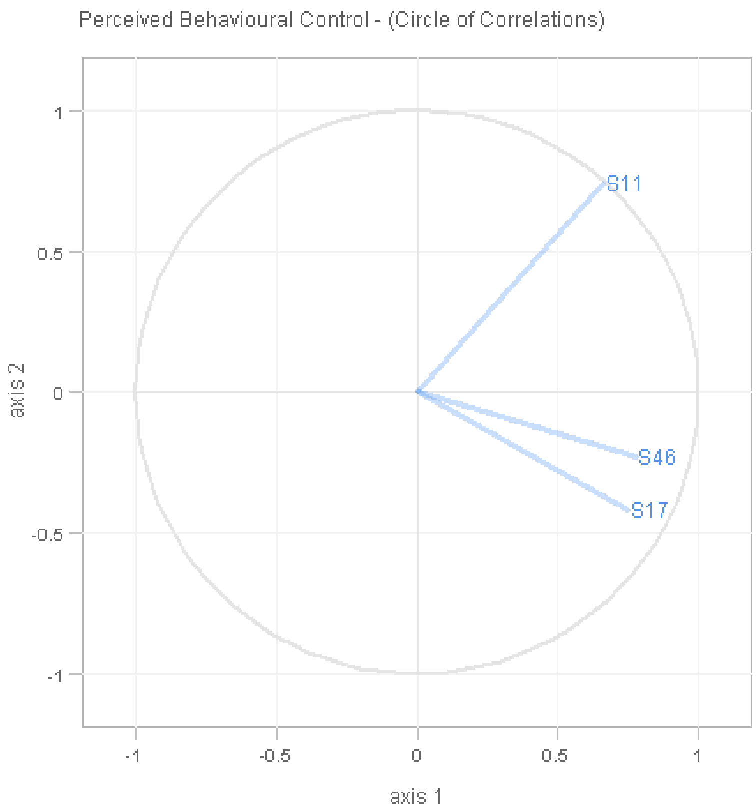


FIGURE 6.3: Circle of Correlations Chart. All Perceived Behavioural Statements
S11:'I am physically fit enough to cycle regularly'
S17: 'I would be confident making minor repairs to a bicycle (e.g. a puncture)'
S46: 'I am confident sharing the road with traffic when cycling'

6.2.3 *Subjective Norms*

The construct of Subjective Norms is derived from the Theory of Planned Behaviour (Ajzen, 1991).

As described in Section 5.4.3 the original version of the main survey did not have the statements relating to whether friends and family would approve of cycling (Statements S24 and S25). These were added after initial analysis found that the statements originally intended to represent Subjective Norms did not perform adequately as a construct within initial analysis of the September 2016 dataset due to low levels of convergent reliability and convergent validity. In the updated version, statements 24 and 25 were included alongside the statements originally intended to represent this construct; statements S4 and S22.

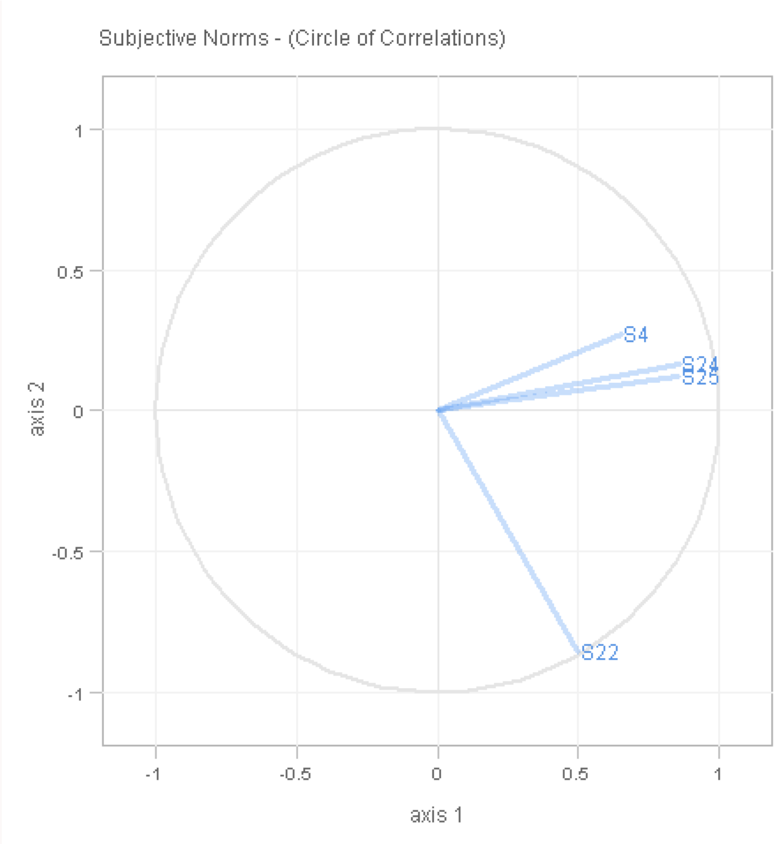


FIGURE 6.4: Circle of Correlations - All Subjective Norms Statements
S4: 'Many people I know cycle'
S22: 'I was encouraged to cycle when I was a child'
S24: 'My friends would approve if I rode a bike/do approve that I ride a bike'
S25: 'My family would approve if I rode a bike/do approve that I ride a bike'

The Circle of Correlations for this construct shows that the three of the statements are aligned, but that statement 22 *"I was encouraged to cycle when I was a child"* appears to be an outlier. The statement was designed to capture a parent's support for cycling but appears not to fit well with the statements regarding the attitudes of respondents' current friends, family and other peers. Based on this S22 was not included in the first iteration of the model specified below (Section 6.3).

6.2.4 *Safety*

From the initial Circle of Correlations plot (Figure 6.5), statement 48 *"Cycling after dark is more dangerous because it is harder for drivers to see you"* stands out as an outlier. The response pattern to statement 48, with 83.3% of respondents agreeing to the statement, also suggests that it may not be a useful indicator of different levels of safety, Thus, this statement can be omitted from this group and was not used in the model specified in the first iteration (Section 6.3).

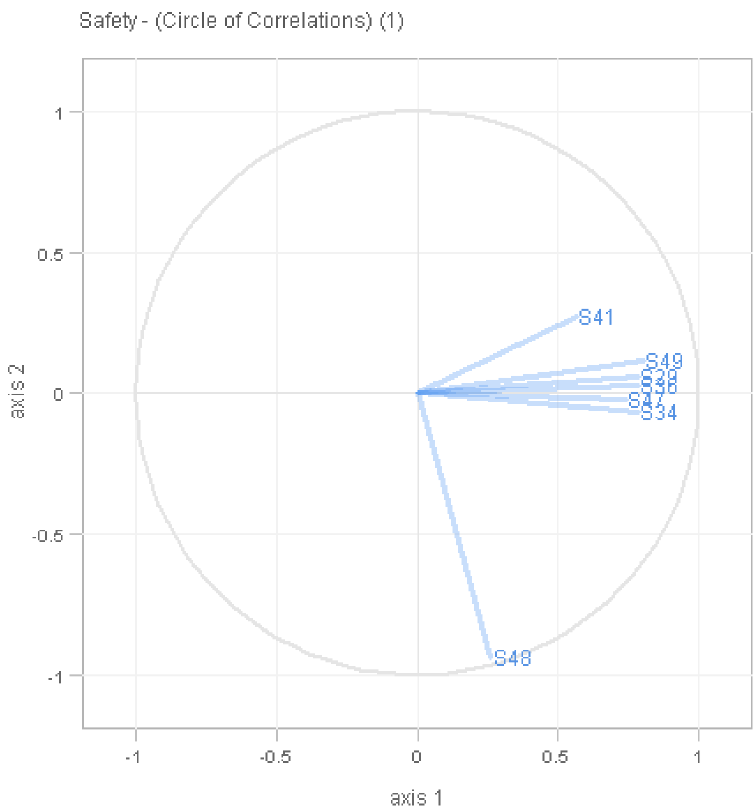


FIGURE 6.5: Circle of Correlations - All Safety Statements
S29: 'Cyclists are provided with sufficient protection at roundabouts'
S34: 'Cyclists are protected on roads with fast moving traffic'
S36: 'Car/van drivers give cyclists enough time and space'
S41: 'The residential roads in my area are safe for cycling'
S47: 'Bus/HGV drivers give cyclists enough time and space'
S48: 'Cycling after dark is more dangerous because it is harder for drivers to see you'
S49: 'Cyclists are provided with sufficient protection at junctions and when crossing side roads'

On the second iteration, Statement 41 *"The residential roads in my area are safe for cycling"* is also identified as a single outlier from the remaining safety indicators. This could be due to the different types of traffic danger perceived between residential roads referred to in S41 and the fast-moving traffic and junctions referred to in the other statements. As residential routes can form an important part of a coherent cycle network (Ettema and Nieuwenhuis, 2017), this statement was subsequently tested as an indicator for the Coherence and Directness construct (Section 6.2.5), to determine which construct it aligns with best.

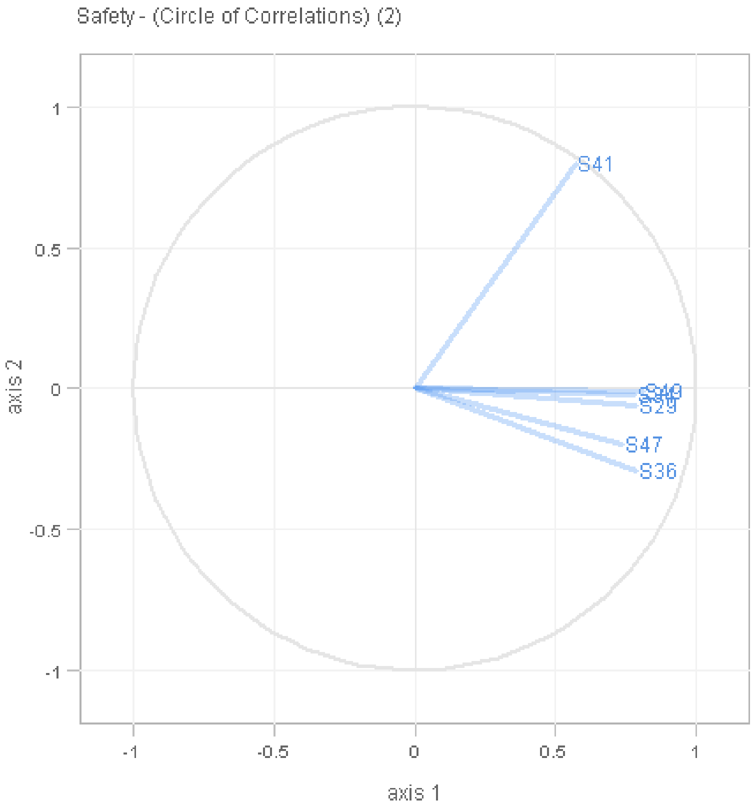


FIGURE 6.6: Circle of Correlations - Safety Statements (S48 removed)
S29: 'Cyclists are provided with sufficient protection at roundabouts'
S34: 'Cyclists are protected on roads with fast moving traffic'
S36: 'Car/van drivers give cyclists enough time and space'
S41: 'The residential roads in my area are safe for cycling'
S47: 'Bus/HGV drivers give cyclists enough time and space'
S49: 'Cyclists are provided with sufficient protection at junctions and when crossing side roads'

6.2.5 *Coherence and Directness*

The initial Circle of Correlations analysis for this group (Figure 6.7) shows one outlier, S30, regarding the right of way given to cyclists. Looking back at the descriptive analysis (section 5.3.2), the response pattern for S30 *"cycling journeys are stop start because cyclists are not given right of way"* shows that a high proportion of non-cyclists provided a neutral response regarding this issue (51%). It may be that this statement does not act adequately as a reflective statement about the quality of cycling infrastructure for this group as it requires too high a level of knowledge.

Based on this interpretation, this statement is removed at this stage and is not included in the model specified in the first iteration (Section 6.3).

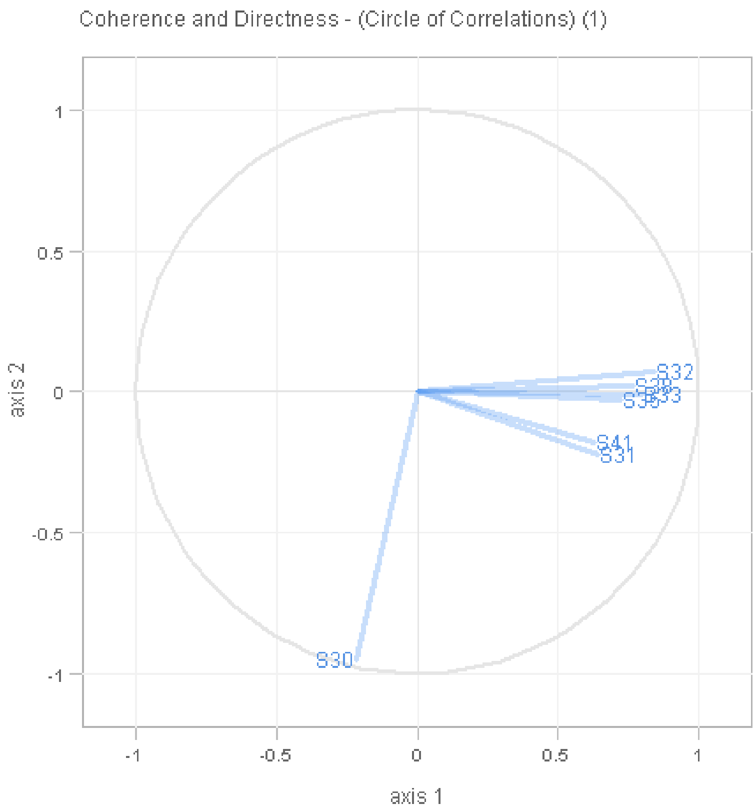


FIGURE 6.7: Circle of Correlations - All Coherence and Directness Statements
S30: 'Cycling journeys in my area are stop-start because cyclists are not given right of way'
S31: 'It is clear where people are allowed to cycle and where they are not'
S32: 'The cycle routes in my area are well joined up'
S33: 'There are lots of cycle routes where I live'
S35: 'It is easy to find and follow a suitable route when cycling somewhere for the first time'
S38: 'The cycle routes in my area protect cyclists from parked cars and opening car doors'
S41: 'The residential roads in my area are safe for cycling'

6.2.6 *Comfort and Attractiveness*

As with the issues of *Coherence and Directness*, it is hard to disentangle the topics around *Comfort and Attractiveness* since many of the issues which impact on one also affect the other. Because of this, the Circle of Correlations may be particularly useful in this case to determine whether one overall construct is appropriate or whether the issues were sufficiently distinct for two separate constructs to be included in the model.

Reviewing Figure 6.8 shows that two clear groups are revealed. The smaller group (S27, S28 and S44) relate to bike storage and maintenance. These are issues that can be considered to be covered under the heading Attractiveness. The larger group (S20, S26, S37, S40, S42 and S45) relate to different aspects of Comfort, associated with factors such as the route surface (S26), security (S40, S42) and traffic fumes (S45).

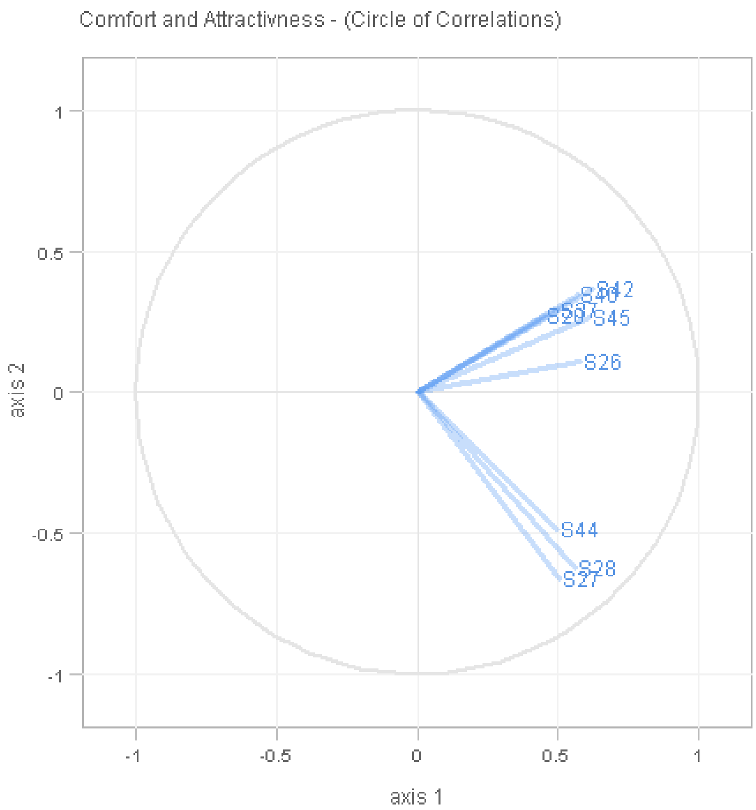


FIGURE 6.8: Circle of Correlations - All Comfort and Attractiveness Statements
S20: 'My friends and family would/do worry about me getting hurt riding a bike'
S26: 'Poor quality surfaces on roads and cycle routes cause problems for cyclists in my area'
S27: 'The cycle routes in my area are well cleared/gritted in winter'
S28: 'The cycle routes in my area are attractive and well kept'
S37: 'Poorly placed street furniture/signs cause obstructions on cycle routes in my local area'
S40: 'You are vulnerable to violent crime when cycling alone after dark'
S42: 'You are vulnerable to verbal abuse when cycling'
S44: 'It is easy to securely park your bike when out and about'
S45: Cycling in my area is unpleasant due to traffic fumes'

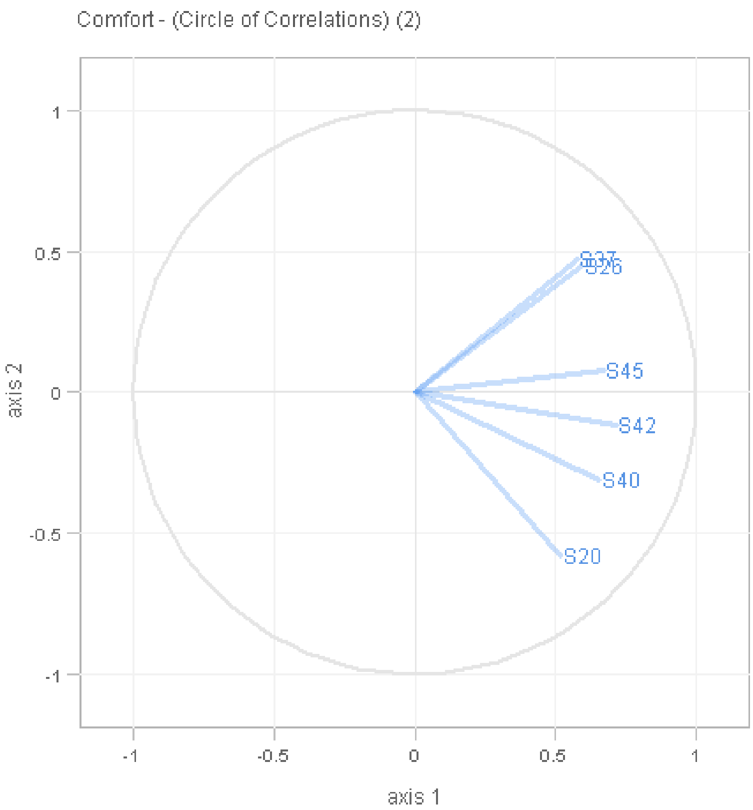


FIGURE 6.9: Circle of Correlations - Comfort Statements Only
S20: 'My friends and family would/do worry about me getting hurt riding a bike'
S26: 'Poor quality surfaces on roads and cycle routes cause problems for cyclists in my area'
S37: 'Poorly placed street furniture/signs cause obstructions on cycle routes in my local area'
S40: 'You are vulnerable to violent crime when cycling alone after dark'
S42: 'You are vulnerable to verbal abuse when cycling'
S45: 'Cycling in my area is unpleasant due to traffic fumes'

Removing the statements relating to *Attractiveness* and repeating the process, two potential sub-groups become apparent within the *Comfort* construct (Figure 6.9). One sub-group could be considered to include security (S20, S40 and possibly S42) and another one regarding broader comfort in the experience (S26, S37 and possibly S45). Nevertheless, the sub-groupings are not entirely clear-cut and thus, initially, these will be tested as a single construct.

The indicators are included as two constructs (*Attractiveness* and *Comfort*) within the first iteration (Section 6.3).

6.2.7 *Journey Quality*

Four statements were designed for inclusion in the construct representing *Journey Quality*. Within the structural model this construct acts at an intermediate level between the constructs relating to specific elements of the perceived local environment and the *Intention to Cycle*.

Analysing the Circle of Correlations for this construct shows that for all four statements are strongly aligned along axis 1. The statements relating to the safety and simplicity and comfort for the respondent are grouped separately from those relating to the respondent's view of a child's experience.

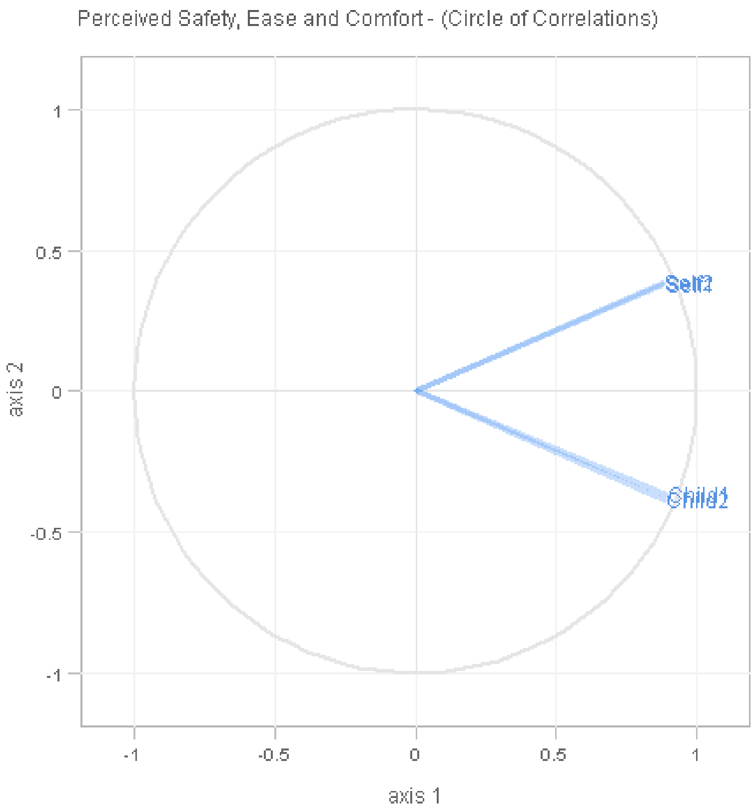


FIGURE 6.10: Circle of Correlations - All Journey Quality Statements
Self1: 'Thinking about if you were to make a journey by bike in your local area how confident are you that your journey would be safe?'
Self2: '...how confident are you that your journey would be comfortable and simple to make?'
Child1: 'Thinking about if a secondary school child (11-16 years old) were to make an unaccompanied journey by bike in your local area confident are you that their journey would your journey would be safe?'
Child2: '...how confident are you that their journey would comfortable and simple to make?'

6.3 Improving Model Performance

The model was tested against the parameters set out in Section 3.9 and using the workflow for model development set out in Section 3.4 which is repeated here.

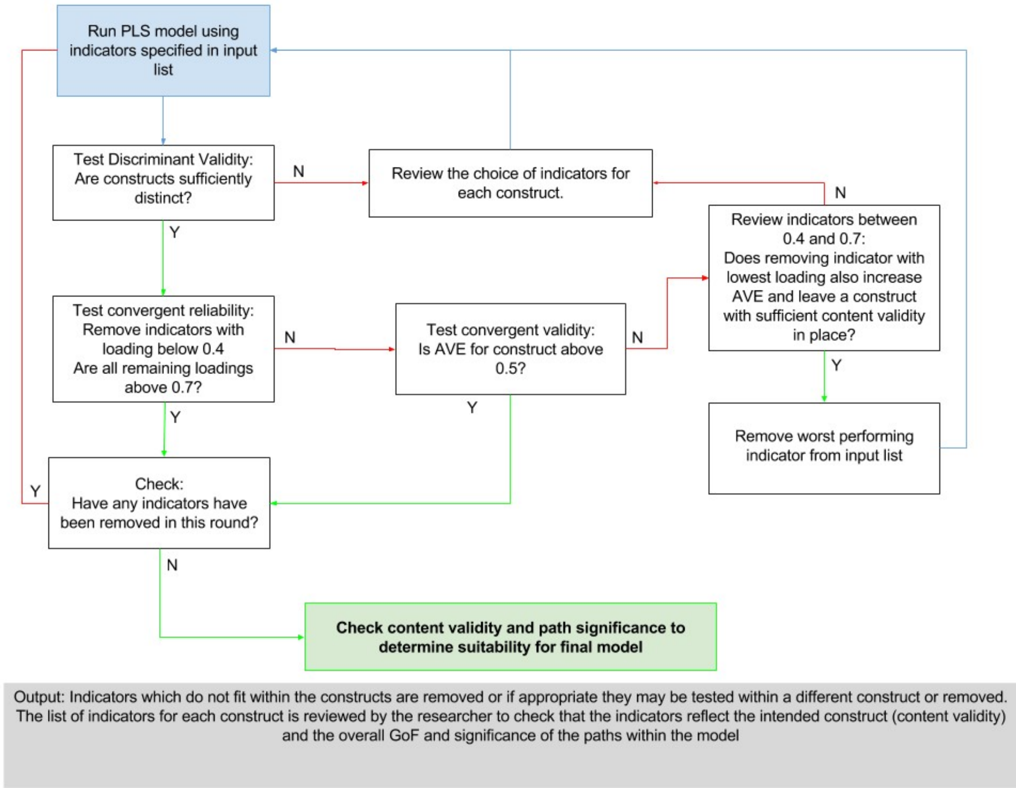


FIGURE 6.11: Summary of the Iteration Process used to Develop the Final Model

Statements S22, S30, S43 and S48 had been removed before the first iteration of the model. In each case the reasons for their removal are specified within the description of the relevant construct (Section 6.2).

In addition to the rules set out in Figure 6.11 it may also be necessary to alter constructs or remove them from the model entirely if the validity tests are not able to be met while maintaining three or more indicators (or reduced to a single indicator) as using two indicators can produce unreliable results (Hair, Mult et al., 2014). In these cases the theoretical and mathematical integrity of the model must be balanced. Constructs which do not have significant path coefficients should be considered for removal (Hair, Mult et al., 2014), however, they can be retained if they are deemed to be theoretically important as their non-significance may be useful information when interpreting the findings in comparison to previous research or in testing the initial hypothesis (Ringle and Sarstedt, 2015).

Construct		No.	α	ρ	AVE	Fornell Larcker Criterion
Attitudes Towards Cycling	Positive	S1, S2, S3, S7, S13, S16, S21	0.91	0.93	0.65	TRUE
	Negative	S5, S6, S14, S23	0.5	0.73	0.37	TRUE
Subjective Norms		S4, S24, S25	0.74	0.85	0.66	TRUE
Perceived Behavioural Control		S11, S17, S46	0.56	0.77	0.53	TRUE
Perceptions	Convenience of cycling	S12, S15, S18, S19	0.77	0.85	0.59	TRUE
	Journey Suitability	S8, S9,S10, S39	0.38	0.68	0.34	TRUE
	Safety	S29, S34, S36, S47, S49	0.85	0.89	0.62	TRUE
	Coherence and Directness	S31, S32, S33, S35, S38, S41	0.83	0.88	0.54	FALSE
	Attractiveness	S27, S28, S44	0.7	0.84	0.63	TRUE
	Comfort	S20, S40, S42, S26, S37, S45	0.68	0.79	0.38	TRUE
Infrastructure density		D1	1	1	1	TRUE
Journey Quality		Self1, Self2, Child1, Child2	0.91	0.93	0.78	TRUE
Intention to Cycle		BI1	1	1	1	TRUE

TABLE 6.1: Validity Tests for the First Iteration of the Model

The measure of Internal Consistency Reliability highlights that, of the constructs generated in the previous stage of model development, only *Journey Suitability* (rho =

0.68) performs below the required level based upon the Dillon-Goldstein's rho measure. On the other hand, several other constructs (*Negative Attitudes Towards Cycling*, *Perceived Behavioural Control*, *Journey Stability*, *Comfort*) fall below the 0.7 threshold when assessed using the more conservative Cronbach's alpha measure. Cronbach alpha has been reported to have a tendency to bias against small groups of indicators (Sarstedt, Hair et al., 2016). As these constructs have relatively few indicators (only *Comfort* which falls just below 0.7 has more than four), this is to be expected and may not be an issue where the constructs perform well on the other measures.

Journey Suitability also does not perform adequately as a construct as assessed by the AVE measure of *Convergent Reliability* (AVE = 0.34). By this measure, the *Negative Attitudes* (AVE = 0.37) and *Comfort* (AVE = 0.38) constructs also fall below the threshold of 0.5.

In order to address these issues, indicators can be moved across constructs or removed from the analysis. Changes were based on an assessment of the loadings and cross-loadings of the individual indicators to test for indicators which may not have been allocated to the most appropriate construct. All indicators meet the looser requirement for Discriminant Validity which states that the loading for a construct must be greater than for any of its cross-loadings with other constructs, however performing Fornell-Lanker test shows that the Coherence and Directness construct is too closely correlated with the Attractiveness construct (AVE = 0.54 correlation = 0.78).

The Goodness of Fit (GoF) value calculated using the method described in Section 3.9 for this iteration of the model is 0.43.

The changes suggested by the outputs described here were addressed in Iteration Two.

6.3.1 *Iteration Two*

Because of the discriminant validity issues identified above, the statements were rearranged to create a clearer distinction. The statements originally grouped within *Attractiveness* construct (S27), (S28), (S44) were moved to the *Coherence and Directness* construct as in each case this was the construct with which they had the highest cross-loading.

Construct		No.	α	ρ	AVE	Fornell Larcker Criterion
Attitudes Towards Cycling	Positive	S1, S2, S3, S7, S16, S21	0.91	0.93	0.70	TRUE
	Negative	S5, S6, S14, S23	0.50	0.73	0.37	TRUE
Subjective Norms		S4, S24, S25	0.74	0.85	0.66	TRUE
Perceived Behavioural Control		S4, S17, S46	0.56	0.77	0.53	TRUE
Perceptions	Convenience of Cycling	S12, S13, S15, S18, S19	0.79	0.86	0.55	TRUE
	Journey Suitability	S8, S9, S10, S39, S43	0.33	0.63	0.26	TRUE
	Safety	S29, S34, S36, S47, S49	0.85	0.89	0.62	TRUE
	Coherence and Directness	S27, S28, S31, S32, S33, S35, S38, S41, S44	0.88	0.91	0.51	TRUE
	Comfort	S20, S26, S37, S40, S42, S45	0.68	0.79	0.38	TRUE
Infrastructure Density		ID	1	1	1	TRUE
Journey Quality		SelfEasy, ChildEasy, SelfSafe, ChildSafe	0.91	0.93	0.78	TRUE
Intention to Cycle		BI1	1	1	1	TRUE

TABLE 6.2: Validity Tests for Second Iteration of the Model

Following these changes, the Fornell-Lanker and individual indicator tests show acceptable discriminant validity, and all constructs (except for *Journey Suitability*) show acceptable levels of internal consistency reliability based on the Dillon-Goldstein's Rho Measure. However, the issues identified above for the *Journey Suitability*, *Negative Attitudes* and *Comfort* constructs have not yet been addressed.

The GoF for this iteration of the model is 0.42 suggesting that while the changes made have addressed the Discriminant Validity issue they have not improved the overall performance of the model.

6.3.2 *Iteration Three*

While iteration two dealt with Discriminant Validity issues between constructs, the aim of iteration three was to address the construction of the constructs relating to *Journey Suitability*, *Comfort* and *Negative Attitudes* as these did not meet the required performance for Internal Composite Reliability and Convergent Validity thresholds within iteration one and two. In order to address these issues, statements with a loading of less than 0.4 were removed as they are below the recommended threshold (Hair, Mult et al., 2014). Thus statement 6 was removed from *Negative Attitudes* (loading = 0.32) and statements 9 (loading = 0.39) and statement 39 (loading = 0.37) were removed from *Journey Suitability*.

Construct		No.	α	ρ	AVE	Fornell Larcker Criterion
Attitudes Towards Cycling	Positive	S1, S2, S3, S16, S7, S21	0.91	0.93	0.65	TRUE
	Negative	S14, S23, S5	0.40	0.72	0.45	TRUE
Subjective Norms		S24, S25, S4	0.74	0.85	0.66	TRUE
Perceived Behavioural Control		S17, S46, S11	0.56	0.77	0.53	TRUE
Perceptions	Convenience of Cycling	S13, S12, S18, S19, S15	0.77	0.85	0.59	TRUE
	Journey Suitability	S10, S8, S43	0.17	0.60	0.37	TRUE
	Safety	S34, S49, S29, S36, S47	0.85	0.89	0.62	TRUE
	Coherence and Directness	S31, S35, S32, S33, S38, S41, S27, S28, S44	0.88	0.91	0.51	TRUE
	Comfort	S45, S37, S26, S20, S40, S42	0.68	0.79	0.38	TRUE
Infrastructure Density		ID	1	1	1	TRUE
Journey Quality		SelfEasy, ChildEasy, SelfSafe, ChildSafe	0.91	0.93	0.78	TRUE
Intention to Cycle		BI1	1	1	1	TRUE

TABLE 6.3: Validity Tests for the Third Iteration of the Model

Running the model for this iteration found that while these changes slightly improved the performance of the model (GoF = 0.43) and improved the Internal Consistency Reliability with all constructs meeting the 0.7 threshold for Dillon-Goldstein's rho.

However, the AVE values for *Negative Attitudes* (AVE=0.45), *Journey Suitability* (AVE = 0.37) and *Comfort* (AVE = 0.38) were still below the required level, indicating that the

Convergent Validity issues for these constructs were still present. This was addressed by further changes in iteration four.

6.3.3 *Iteration Four*

As the *Negative Attitudes* construct had only 3 indicators remaining in that iteration it was not considered appropriate to remove a further indicator since it has been recommended that PLS constructs with less than 3 indicators can be unreliable and should be avoided (Rigdon, 2016). As the construct is not necessary to the theory-led structure of the model and was originally hypothesized as part of an overall attitudes construct which is still represented by *Positive Attitudes* it was removed from the model at this stage.

The *Comfort* construct also exhibited a poor level of Convergent Validity. Re-examining the Content Validity of this construct, the statements relating to traffic fumes (S45), friends and family concern (S20), crime and verbal abuse (S40 and S42) all have high loadings and may be taken together as aspects which relate to a feeling of vulnerability, this construct was renamed *Feeling Comfortable*. Thus, the statements relating to the placement of street signs (S37) and surface issues (S26) were removed.

As a result of the changes to the *Comfort* construct, it should be noted that it now relates differently to the CROW guidance on which this model was originally based. The constructs relating to the environment now cover danger from road traffic (included in the Safety construct), provision of a coherent network (included in the *Coherence and Directness* construct) and vulnerability (included in the now modified *Feeling Comfortable* construct). This means that some issues, such as route surface quality, are not directly included in the model. However, as the model is built using reflective indicators it is judged that these issues are captured by the *Coherence and Directness* and *Feeling Comfortable* constructs.

Following Iteration Three *Journey Suitability* construct had 3 indicators and required adjustment based on the convergent validity level. However, the statement regarding journey length has the highest loading for this construct (0.688). Within the Literature Review (see Chapter 2) this issue is known to be particularly significant from previous research and is included in almost all cycling studies (Heinen, van Wee and Maat, 2010). Based on this and the lack of statements elsewhere in the model that were felt to address this issue this indicator was retained as a single indicator construct renamed *Journey Length* in line with the recommendations of Hair, Mult et al. (2014).

Construct		No.	α	ρ	AVE	Fornell Larcker Criterion
Attitudes Towards Cycling	Positive	S2, S3, S7, S13, S16, S21	0.91	0.93	0.65	TRUE
Subjective Norms		S4, S24, S25	0.74	0.85	0.66	TRUE
Perceived Behavioural Control		S11, S17, S46	0.56	0.77	0.53	TRUE
Perceptions	Convenience of Cycling	S12, S15, S18, S19	0.77	0.85	0.59	TRUE
	Journey Length	S10	1	1	1	TRUE
	Safety	S29, S34, S36, S47, S49	0.85	0.89	0.62	TRUE
	Coherence and Directness	S27, S28, S31, S32, S33, S35, S38, S41, S44	0.88	0.91	0.51	TRUE
	Feeling Comfortable	S20, S40, S42, S45	0.63	0.78	0.47	TRUE
Infrastructure Density		ID1	1	1	1	TRUE
Journey Quality		SelfEasy, ChildEasy, SelfSafe, ChildSafe	0.91	0.93	0.78	TRUE
Intention to Cycle		BI1	1	1	1	TRUE

TABLE 6.4: Validity Tests for the Fourth Iteration of the Model

These changes improved the performance of the model (GoF = 0.45) with all constructs displaying adequate convergent validity and internal consistency reliability and discriminant validity. All indicators having outer loadings of at least 0.4 with many having over the recommended level of 0.7 which indicates a high level of indicator reliability.

6.3.4 *Iteration Five and Iteration Six*

Construct		No.	α	ρ	AVE	Fornell Larcker Criterion
Attitudes Towards Cycling	Positive	S1, S2, S3, S7, S13, S16, S21	0.91	0.93	0.70	TRUE
Subjective Norms		S4, S24, S25	0.74	0.85	0.66	TRUE
Perceived Behavioural Control		S11, S17, S46	0.56	0.77	0.53	TRUE
Perceptions	Convenience of Cycling	S12, S15, S18, S19	0.77	0.85	0.55	TRUE
	Journey Length	S10	1	1	1	TRUE
	Safety	S29, S34, S36, S47, S49	0.85	0.89	0.62	TRUE
	Coherence and Directness	S27, S28, S31, S32, S33, S35, S38, S41, S44	0.88	0.91	0.51	TRUE
	Feeling Comfortable	S20, S40, S42, S45	0.63	0.78	0.47	TRUE
Infrastructure Density		ID1	1	1	1	TRUE
Journey Quality		SelfEasy, ChildEasy, SelfSafe, ChildSafe	0.91	0.93	0.78	TRUE
Intention to Cycle		BI1	1	1	1	TRUE

TABLE 6.5: Validity Tests for the Fifth Iteration of the Model

The final iterations of the model investigates the structural model to test for significant relationships which suggest that the links within the model are valid. It also examines the content validity of the constructs to determine whether any indicators with lower than 0.7 can be removed to improve content validity or other performance measures.

Positive Attitudes: The *positive attitudes* construct shows good performance, with all but statement 13, which relates to freedom and independence, having outer loadings of 0.7 or larger. Removing statement 13 could improve the content validity by focussing the constructs content on motivations to cycle. Based on the stable result for improvement in AVE (remains at 0.70) and the Content Validity judgement this statement is removed.

Subjective Norms: The construct relating to subjective norms demonstrates adequate performance with the lowest outer loading (S4) being only just below 0.7. Removing this statement would reduce the reliability of the construct (Rigdon, 2016) and the performance measures are adequate, so it was retained. The low path coefficient for *Subjective Norms* is in line with previous research (Armitage and Conner, 2001).

While Bootstrap analysis shows that this construct is not significant ($p = 0.17$ for link with *Intention to Cycle*), it is a core part of the Theory of Planned Behaviour and thus it was retained.

Perceived Behavioural Control: This construct is also made up of only 3 indicators, so removing any indicators would reduce the reliability of the construct and, in this case, it would also reduce the Content Validity of the construct thus no changes were made.

Convenience of Cycling: All of the indicators for this construct have loadings over 0.7 and so were retained.

Journey Length (Formerly Journey Suitability): Bootstrap analysis shows that this path coefficient is significant ($p < 0.001$ for link with *Intention to Cycle*). The inclusion of a construct such as this is also backed up by research (Heinen, 2011) so it is retained.

Safety: The loadings for all indicators are above 0.7, suggesting that this construct may be suitable for retention. However, bootstrap analysis shows that this is not a significant factor to 95% ($p = 0.087$ for link with *Journey Quality*). While safety is an important element, the statements surrounding the coherent network also provide information on elements of the cycling infrastructure that protect cyclists from motor traffic. Thus, the *Safety* construct was removed in order to improve the performance of the model due to its lack of significance in the bootstrap analysis.

Coherence and Directness: The loadings for all indicators included in this construct are above 0.7 and the construct demonstrates good performance, so all indicators were retained.

Feeling Comfortable (Formerly Comfort): Following removal of the indicator dealing with route surface (S26) only the indicator relating to traffic fumes (S45) has a loading above 0.7. However, removing the statement relating to verbal abuse (S42) shifts the AVE above the threshold of 0.5 (0.47 increased to 0.50) so this indicator was removed. Bootstrap testing (p-value <0.001) shows this construct is significant and content validity was judged to be good so it was retained.

Infrastructure Density: This is a single indicator construct. Bootstrap analysis shows it is significant so is retained (p value for link to *Intention to Cycle* is 0.048).

Journey Quality: All indicators have loadings above 0.7 and bootstrap analysis confirms significant links both to *Intention to Cycle* and from *Feeling Comfortable* and *Coherence and Directness* constructs. Not to be adjusted.

Intention to Cycle: This is a single indicator construct which as the target variable demonstrates significant links from exogenous constructs, so it was retained.

Making these changes between Iterations Five and Six improved the GoF from 0.45 to 0.46. Following this iteration no further changes were considered necessary based on the validity tests and so this is regarded as the final model.

6.4 Analysis of the final model

Following the process of iterations to improve model performance a model which met the required performance measures (Hair, Mult et al., 2014) was developed. The results from this model when applied to the dataset as a whole (containing both Upper Band and Lower Band) are shown in Figure 6.12 and Tables 6.6, 6.7 and 6.8.

These results show that the highest path coefficient for constructs which were directly linked to *Intention to Cycle* were *Positive Attitudes* (0.255) and *Convenience of Cycling* (0.222). The only link within the final model which was not found to be significant when the model was applied to the whole dataset was between *Subjective Norms* and *Intention to Cycle* (path coefficient = 0.037).

The model built using the whole dataset is then applied to subgroups within the data to explore the similarities across cycling levels, demographic factors and between groups based on data-led segmentation.

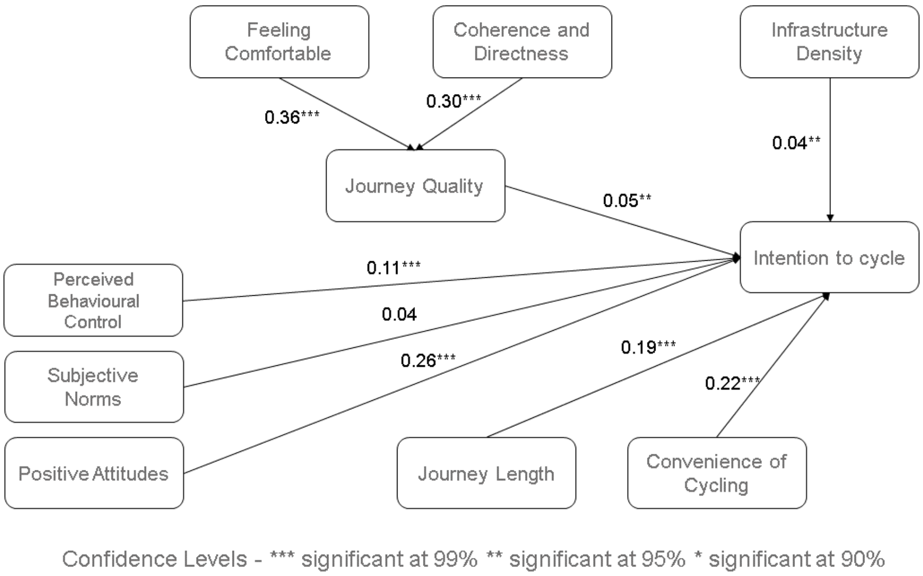


FIGURE 6.12: Path Diagram for final model based on combined dataset of Upper and Lower Band used for model development

Construct		Dillon-Goldstein Rho			Average Variance Explained		
	No. indicators	Whole data	Upper Band	Lower Band	Whole data	Upper Band	Lower Band
Positive Attitudes	6	0.93	0.87	0.91	0.7	0.53	0.64
Subjective Norms	3	0.85	0.82	0.82	0.66	0.6	0.61
Perceived Behavioural Control	3	0.77	0.75	0.72	0.53	0.49	0.46
Convenience of Cycling	4	0.85	0.84	0.81	0.59	0.56	0.51
Journey Length	1	1	1	1	1	1	1
Coherence and Directness	6	0.91	0.91	0.9	0.63	0.63	0.61
Feeling Comfortable	3	0.75	0.77	0.74	0.5	0.52	0.48
Density of Cycle Infrastructure	1	1	1	1	1	1	1
Journey Quality	4	0.93	0.93	0.93	0.78	0.76	0.77
Intention to Cycle	1	1	1	1	1	1	1

TABLE 6.6: Structural model summary for final model

Construct (link to Intention to Cycle unless specified)	Path Coefficient			Group Comparison (AvB)	
	Whole dataset	Upper Band (A)	Lower Band (B)	Absolute difference	P-Value
Positive Attitudes	0.255***	0.158***	0.24***	0.08	0.14
Subjective Norms	0.037	0.01	0.04	0.04	0.255
Perceived Behavioural Control	0.109***	0.029	0.173***	0.143	<0.001***
Convenience of Cycling	0.222***	0.292***	0.051	0.241	<0.001***
Journey Length	0.188***	0.283***	0.078**	0.11	<0.001***
Directness and Coherence TO Journey Quality	0.300***	0.334***	0.225***	0.11	0.008**
Feeling Comfortable TO Journey Quality	0.360***	0.341***	0.374***	0.033	0.231
Infrastructure Density	0.038**	0.056**	0.006	0.062	0.056
Journey Quality	0.053**	0.064**	0.016	0.048	0.145

TABLE 6.7: Summary of path coefficients and comparison of Upper and Lower Band Models Positive values indicate a stronger link for Sample B than Sample A *** significant at 99% ** significant at 95% * significant at 90%

		Loadings			Medians (Negative Statements Reversed)		
	No.	Whole	Up	Lo	Whole	Up	Lo
Positive Attitudes Towards Cycling	S1	0.883	0.744	0.866	5	6	4
	S2	0.825	0.708	0.817	5	5	4
	S3	0.829	0.708	0.826	4	5	3
	S16	0.788	0.707	0.683	5	6	5
	S7	0.911	0.829	0.889	5	6	4
	S21	0.783	0.657	0.687	5	6	3
Subjective Norms	S24	0.875	0.871	0.874	5	6	4
	S25	0.867	0.839	0.862	5	6	4
	S4	0.686	0.589	0.558	4	5	3
Perceived Behavioural Control	S17	0.685	0.665	0.707	5	5	4
	S46	0.74	0.67	0.639	3	4	3
	S11	0.756	0.768	0.677	5	6	5
Convenience of Cycling	S12	0.774	0.787	0.73	4	4	3
	S18	0.726	0.659	0.605	5	5	4
	S19	0.773	0.727	0.754	5	5	4
	S15	0.801	0.799	0.764	4	5	3
Journey Length	S10	1	1	1	4	4	4
Coherence and Directness	S35	0.73	0.743	0.702	4	4	4
	S32	0.862	0.863	0.858	4	4	4
	S33	0.805	0.801	0.799	4	4	4
	S38	0.761	0.775	0.741	4	4	4
	S27	0.732	0.725	0.743	4	4	4
	S28	0.849	0.847	0.844	4	4	4
Feeling Comfortable	S45	0.747	0.742	0.766	4	4	4
	S20	0.727	0.76	0.717	3	3	3
	S40	0.652	0.656	0.577	3	4	3
Infrastructure	I1	1	1	1	-	-	-
Journey Quality	Self2	0.892	0.866	0.886	5	7	4
	Child2	0.867	0.88	0.857	5	5	4
	Self1	0.896	0.862	0.897	5	7	3
	Child1	0.875	0.879	0.872	4	5	4
Intention to Cycle	BI1	1	1	1	1	2	1

TABLE 6.8: Summary of retained indicators in final model

6.4.1 *Analysis of Upper and Lower Band Models*

Figures 6.13 and 6.14 present the results from the PLS-SEM models for the Upper and Lower Band within a Importance-Satisfaction matrix (Hair, Mult et al., 2014). These charts combine information about the average 'satisfaction' with each construct and its importance in relation to *Intention to Cycle*. To enable comparison across groups the crosshairs are based on the mean values based on the full dataset used within this analysis (Yahya, 2013). Issues in the bottom right quadrant can be treated as priority issues as they have low satisfaction and high importance. *Infrastructure Density* was removed for presentation within these charts as, unlike the indicators for the others constructs it is not measured on a self-reported scale.

This highlights the low level of satisfaction for within Lower Band respondents as none of the constructs are above the y-axis of the crosshair. In addition to this all but *Feeling Comfortable*, *Coherence and Directness* and *Journey Quality* are with the bottom right quadrant indicating high priority. This both indicates that many issues need to be tackled to encourage and enable this group to cycle but also as the 'low priority' constructs are all related to the cycling environment it can be seen that perceptions of the environment do not help differentiate between respondents within this band.

Comparing this to the Upper Band shows some similarities and some differences. More of the constructs fall above the y-axis crosshair, indicating a more positive view. However, *Coherence and Directness*, *Feeling Comfortable* and *Journey Quality* all fall below. This reinforces the findings, described in Chapter 5, that all groups have a poor perception of the cycling environment.

Two constructs fall within the top right quadrant which indicates high satisfaction and high importance. These statements relate to *Positive Attitudes* and *Convenience of Cycling*, reinforcing the conclusion from the path model analysis that these issues encourage these respondents to cycle despite their poor perception of the cycling environment.

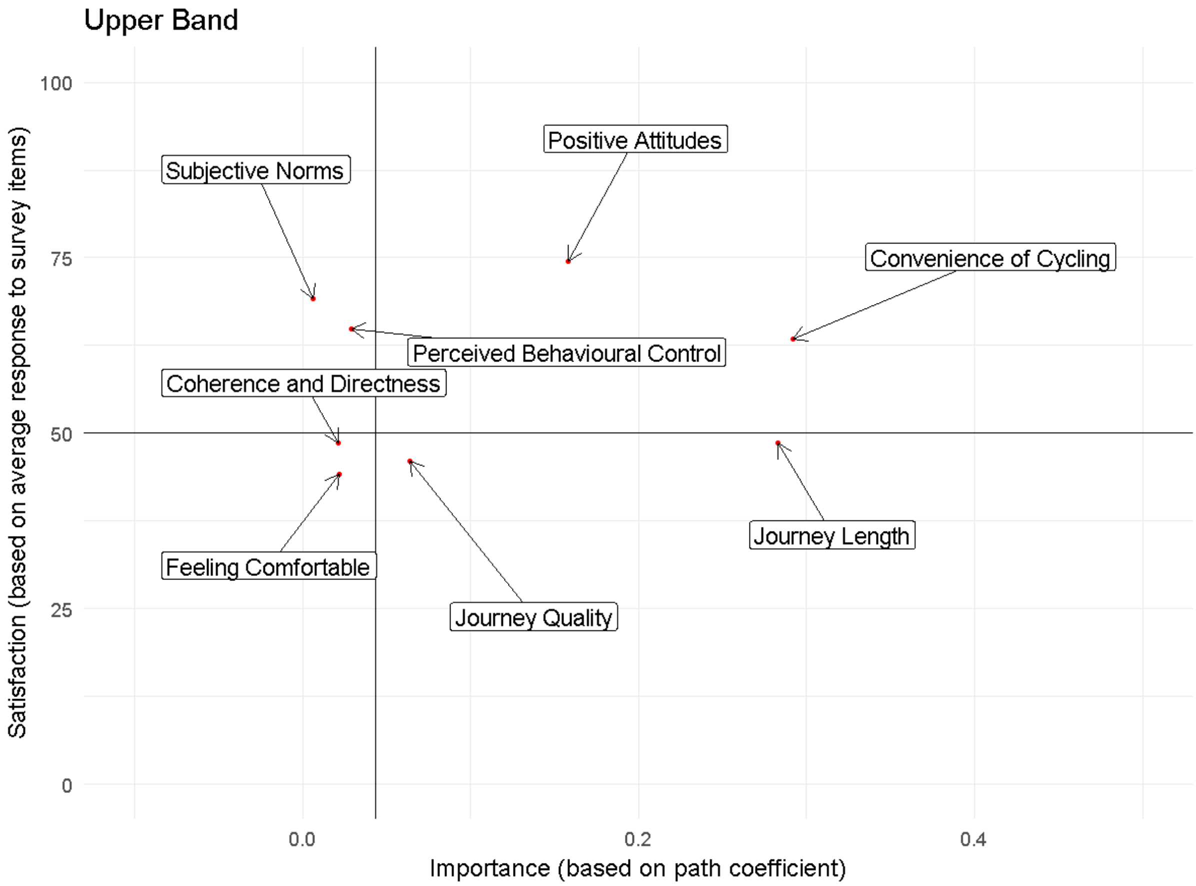


FIGURE 6.13: Importance-Satisfaction Matrix for Upper Band Respondents Based on Final Model

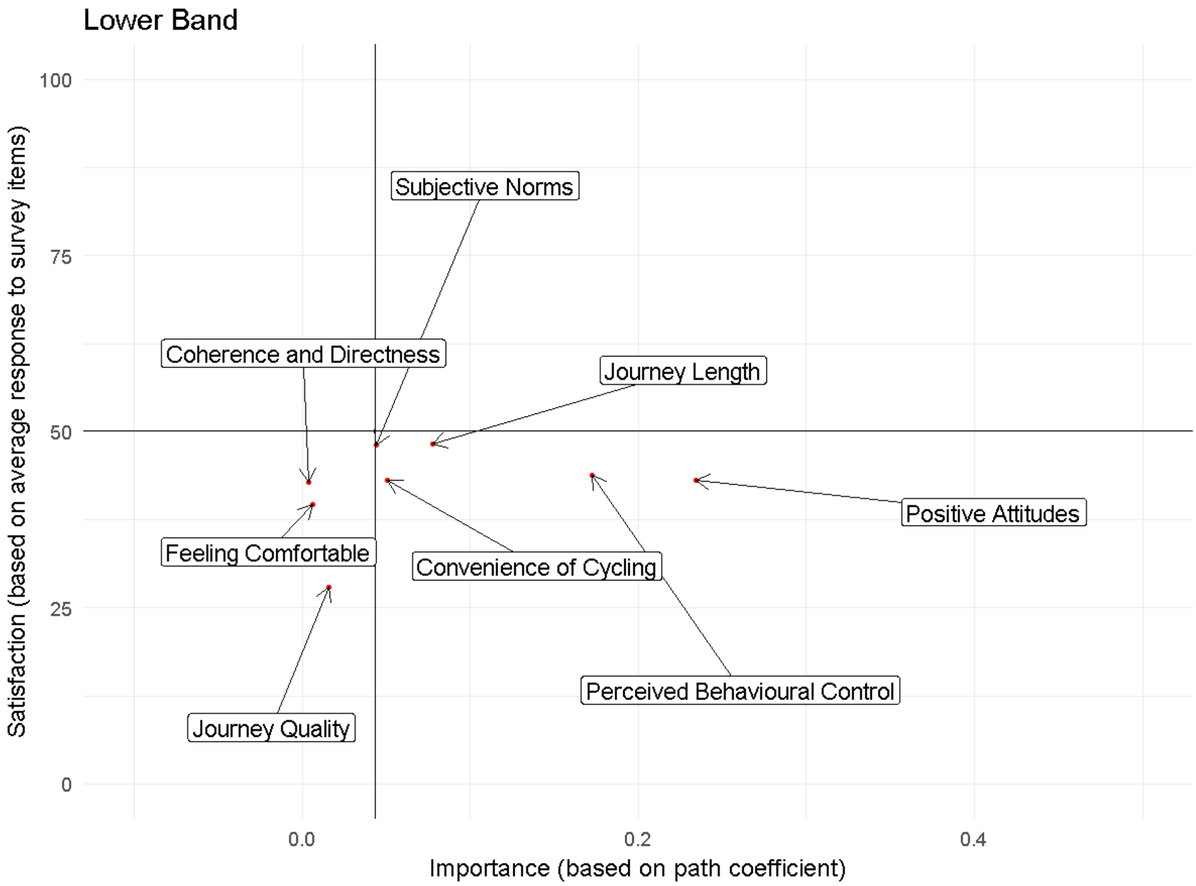


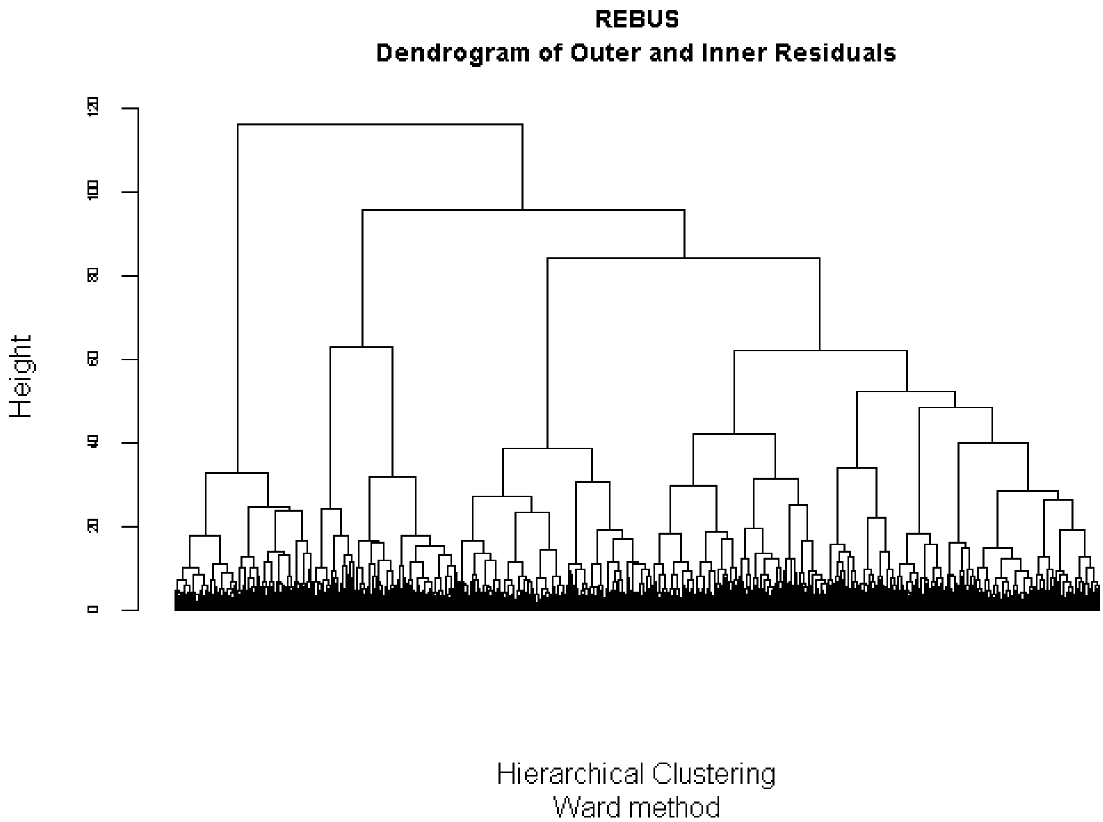
FIGURE 6.14: Importance-Satisfaction Matrix for Lower Band Respondents based on Final Model

6.4.2 *REBUS Analysis*

A dendogram was produced as described in Section 3.8.2 to allow the appropriate number of classes within the data used for the production of the final model to be determined.

Based on the dendrogram shown in Figure 6.15 performances measures were tested based on categorisation into four classes which produced the highest group quality index (Sanchez, 2013).

With four classes all the retained indicator questions pass the minimum requirement for the factor loading, however some other validity measures fall slightly below the desired level so caution should be used in taking conclusions from the findings. An advantage of using four clusters is that allows for comparison to Geller's four types of cyclist (Geller, 2006). The Groups now described in turn. The names given to each



H

FIGURE 6.15: Dendrogram for REBUS Analysis of Data Set used for Final Model

class are informed by the characteristics of the respondents within each class. Where possible names which relate to Geller's four types of cyclist are used to highlight similarities and differences between the two classifications.

	Class 1	Class 2	Class 3	Class 4
GoF	0.71	0.35	0.42	0.56
N	261	569	475	395

TABLE 6.9: Goodness of Fit and number of respondents for each class

	Class 1	Class 2	Class 3	Class 4
Positive Attitudes	0.68	0.65	0.63	0.63
Subjective Norms	0.58	0.64	0.60	0.65
Perceived Behavioural Control	0.47	0.38	0.50	0.52
Convenience compared to other	0.50	0.53	0.51	0.61
Journey Length	1.00	1.00	1.00	1.00
Directness and Coherence	0.64	0.61	0.64	0.60
Feeling Comfortable	0.49	0.47	0.50	0.50
Infrastructure Density	1.00	1.00	1.00	1.00
Journey Quality	0.36	0.50	0.52	0.68
Intention to Cycle	1.00	1.00	1.00	1.00

TABLE 6.10: Average Variance Explained values for each construct by class

Link in Model	Class 1	Class 2	Class 3	Class 4
Positive Attitudes	0.233	0.320	0.262	0.013
Subjective Norms	-0.017	0.088	-0.048	0.080
Perceived Behavioural Control	0.393	0.020	0.167	0.095
Convenience of Cycling	0.383	0.055	0.195	0.532
Journey Length	0.303	0.015	0.212	0.203
Directness and Coherence TO Journey Quality	0.461	0.267	0.292	0.439
Feeling Comfortable TO Journey Quality	0.635	0.266	0.339	0.330
Infrastructure Density	0.097	0.077	0.020	0.021
Journey Quality	0.052	-0.025	0.129	-0.116

TABLE 6.11: Path Coefficients for each class from REBUS Analysis. Link is to Intention to Cycle except Directness and Coherence TO Journey Quality and Feeling Comfortable TO Journey Quality

Concerned Cyclists (Class 1): The final class is a similar class to the first, with 261 respondents, accounting for 15% of the dataset. Within this class there is a range of *Intentions to Cycle*, though the majority of this class are either considering making journeys by bike (35.2%) or are already doing so occasionally (19.2%).

The most important path coefficients for this class are *Journey Length* (0.303) and *Convenience* (0.383) and *Perceived Behavioural Control* (0.393) when looking at Intention to Cycle.

Several in this class have a very low score for the questions relating to a child's experience. This class is also 58.6% female and, given burden of child caring and other household tasks more likely to fall on the female, it might be that this is restricting some from making more frequent journeys by bike.

No Way, No How (almost) (Class 2): Many (73.8%) of this class cycle less than once a month in both the warmer and colder months and none of the respondents report that they ever make their regular journeys by bike, with only 21.1% reporting that they consider doing so.

The overall Goodness of Fit for this class is lower than the others (0.38) and when looking at the *Intention to Cycle* the strongest positive path coefficient is relatively low, with *Positive Attitudes* having a path coefficient of 0.320. Each of the other three classes have at least one link with a higher value than this.

It is the largest of the four classes, with N=569 respondents included. This is 33% of the overall sample used for this analysis.

As 49.6% of Lower Band respondents are grouped into this class there are many similarities between this model and the Lower Band model and there is a lower GoF (0.35) than for the other classes.

One difference is that there is a higher coefficient for the link between *Infrastructure Density* and the *Intention to Cycle* (0.077) compared to 0.006 for the Lower Band model). This may suggest that there is a sensitivity to the presence of cycle infrastructure and that an improvement in the quality as well as availability of infrastructure could encourage some of this cluster to make the step up to making some of their everyday journeys by bike.

Interested potential cyclists (Class 3): N=475 Some of this class consider making their regular journeys by bike (30.7%) but none report doing so regularly. Around half (50.5%) report making journeys at least once a month, in either the warmer or colder months, for any purpose. When examining the constructs associated with the *Intention to Cycle*, *Positive Attitudes* towards cycling has the highest path coefficient for this class (0.262).

Enthused and Confident (Class 4): This is the second smallest class of the four, accounting for 23% of the overall dataset with 395 respondents. This class was the most likely to cycle regularly for utility purposes with 30% reporting that they have been making everyday journeys regularly by bike for some time. The path coefficient of 0.532 between *Convenience of Cycling* and *Intention to Cycle* is the highest positive coefficient for this class. The coefficient for this link is of a similar magnitude for this link to class one (0.383), who are more likely to make their everyday journeys by bike occasionally. In comparison to class one the path coefficient for *Journey Length* is lower (0.203 compared to 0.303).

This class also has a negative path coefficient for the link between the *Journey Quality* and the *Intention to Cycle* (-0.116), as with class 2 (-0.025) this may be explained by the negative correlation between the statements relating to a child's experience and the indicator relating to the *Intention to Cycle*.

'Enthused and Confident' have a low path coefficient for the link between the *Infrastructure Density* and their *Intention to Cycle*. As the descriptive analysis shows that this class is more likely to agree to the statement that they are confident cycling on the road with traffic than others this may relate to the their confidence in their own ability to cycle.

Exploring the distribution of the respondents which have been classified within these groups can help inform the policy recommendations which can be drawn from this analysis. In order to achieve this the sample was divided into four geographic classifications as shown in Table 6.12. Some respondents could not be classified as they preferred not to disclose the type of area they lived in. This shows that the classes are relatively evenly distributed across the geographic areas. Some of the most noticeable differences are within the 'Enthused and Confident' group with 14% from Greater London in comparison to 11.5% of the dataset and 14.8% from rural areas compared to 20.5% of the dataset.

	Class				
	Concerned Cyclists	No Way, No How (almost)	Interested potential cyclists	Enthused and Confident	Total
Greater London	8.1%	12.4%	10.2%	14%	11.5%
Other - Urban	27.3%	26.7%	27.2%	30.6%	27.8%
Other - Suburban	44.2%	37.6%	40.6%	40.6%	40.2%
Other - Rural	20.4%	23.3%	21.9%	14.8%	20.5%
Total n	**260**	**566**	**470**	**392**	**1688**

TABLE 6.12: Geographic distribution of respondents within REBUS classifications

6.4.3 *Sub-group analysis*

As well as comparing the samples based on cycling frequency other demographic data can be used to analyse subgroups and understand the factors which are more important to different groups. Based on the common themes explored within the Literature Review – Chapter 2 comparisons were made along age and gender lines.

The recommended minimum of 5000 runs was performed for each test. Where values close to 0.05 were found with a run of 5000 the test was repeated with 10000 repetitions to provide more certainty in the findings.

6.4.4 *Gender comparison*

Analysis was conducted comparing male and female respondents for both Upper and Lower Band respondents separately and for the whole dataset. No significant differences were found for Lower Band. For Upper Band respondents there were no significant differences relating to the *Intention to Cycle*, though there were differences relating to the *Journey Quality* with *Feeling Comfortable*, demonstrating a stronger link for female cyclists as represented by a higher path coefficient within the model (0.412 compared to 0.254 p-value) and *Coherence and Directness* demonstrating a stronger link for male cyclists (0.403 compared to 0.277 p-value).

Female cyclists appear to have a higher path coefficient for the link between *Infrastructure Density* and *Intention to Cycle* (0.097 compared to 0.042). As the p-value was close to 0.05, repeating tests 5000 runs indicated that this level of test could not show reliability whether the difference was significant to 95% or not. The parameter based on a 10,000 repetition run was found to allow rejection of the null hypothesis (essentially that male and female cyclists place the same value on infrastructure) to a 90%, but not 95% confidence level (p-value = 0.057).

When this test was repeated for the whole dataset, two links were found to be significantly different for male and female respondents. Higher path coefficients between *Perceived Behavioural Control* and *Intention to Cycle* was found for male cyclists (0.157 compared to 0.067, p = 0.03) and, as with the Upper Band test, the link between *Coherence and Directness* and *Journey Quality* was stronger for male respondents.

Again a 10000 repetitions test was conducted based on the links between *Feeling Comfortable* and *Journey Quality* and the links between *Infrastructure Density* and *Journey Quality* and *Intention to Cycle*. In all three cases the p-values were found to fall just above 0.05 meaning these differences do not appear to be significant.

6.4.5 *Age Comparison*

In order to facilitate the use of a stronger test this comparison focused on comparing those aged 60 or over to younger respondents. This comparison was chosen in line with the Cycle Boom study (Jones, Chatterjee et al., 2016) which focuses on the issues which impact on older cyclists.

As with the comparison by gender, no significant differences were found when looking only at Lower Band. When looking at Upper Band more frequent cyclists

Journey Length was found to have a much stronger link for younger respondents (0.312 compared to 0.258 p value 0.003) and Journey Quality had a stronger link for older respondents (0.226 compared to 0.0452 p value = 0.02). Of these only the *Journey Length* difference was found when looking at the dataset as a whole (0.211 compared to 0.086 p value = 0.002).

The importance of *Journey Quality* for older respondents is interesting in that it refers to a group of cyclists and potential cyclists that have been unrepresented in cycling populations in countries with low cycling levels. Aldred, Elliott et al. (2016) reported that the literature contained some evidence of similar effects but called for more research with this group.

6.5 Conclusion

Using the retained indicators, tests for model validity were carried out on the whole dataset and on Upper and Lower Band respondents separately. The aim was to develop a model which allowed these groups to be compared while representing the views of both. The validity tests show that the model generally performs adequately for both bands, but that it performs better for the Upper Band respondents.

The results summarised in Table 6.7 show that many of the links within this model have statistically significant associations with influencing the *Intention to Cycle* and that there are differences between the two bands. *Positive Attitudes Towards Cycling* appear to be more important within the Lower Band while *Convenience of Cycling* is more important within the Upper Band respondents.

Some of the constructs fall under the recommended AVE of 0.5 for the subgroup analysis. These constructs are the *Perceived Behavioural Control* and *Feeling Comfortable* constructs. This suggests that there is more variance between the responses to the indicator statements for these constructs within the subgroups. However, the AVE is only slightly below this level and the other performance measures remain above the required levels. This provides a basis for subgroup analysis as well as the overall analysis of the model for the whole dataset, however the lower AVE values should be noted when assessing the strength of the conclusions which can be drawn from the subset analysis.

The lower Goodness of Fit (GoF) for the Lower Band (0.35 compared to 0.43 for Upper Band) suggests that, while the individual constructs work sufficiently for this group, the model does not explain increased *Intention to Cycle* among these groups. As identified in Chapter 5, this may be because the scale used to measure *Intention to Cycle* did not adequately differentiate within non-cyclists, with a large proportion responding that they had not considered making journeys by bicycle. It appears that this led to reduced performance of the model and limits the insights which can be drawn from it. The existing scale separates out those that are considering cycling from other non-cyclists but, given the size of the group which has not considered cycling, further research may be required to expose differences within this group.

The performance may be improved further by refining the model using data from only this sample. This probably would lead to a different set of retained indicators. While this may be an appropriate approach, it reduces the potential for direct comparison.

Another explanation for the lower fit is that as both the structural and measurement models were substantially based on the literature is itself largely based on studies of cyclists. Thus, it may be that major issues which influence the decision processes of non-cyclists are not included within this model. Taken together the analysis in Chapter 5 and the path model work reported in this chapter help represent the views of the respondents and to assess the influence of each construct on the *Intention to Cycle*.

The Importance-Satisfaction matrices (figures 6.13 and 6.14) show that, on some issues (such as the provision of infrastructure) both groups share similar opinions. On the other hand, on many issues around the benefits of cycling and the perceived safety and comfort of making journeys by bicycle, regular cyclists have more positive views.

Subgroup comparison was conducted comparing respondents based on age and gender and through the creation of segments through REBUS analysis. The REBUS analysis enabled the proposal of four classes within the overall dataset which can be compared to Geller's 'Four types of bicyclist' (Geller, 2006). The most interesting finding from this section of the analysis is a strong link between Journey Quality and Intention to Cycle which applies to older respondents. This may add to the to the evidence base regarding the importance of cycling infrastructure for older cyclists.

Chapter 7. Discussion and Conclusion

The central aim and objectives of this thesis established in Chapter 1 was to provide data and analysis that may help inform policy decisions to enable a broader population to cycle for utility purposes than is currently found in countries with low cycling mode shares, such as the UK. A broad population engaged in utility cycling is necessary to increase cycling levels substantially and maximise the benefits to society, the environment and individuals. The objectives set out in Chapter 1 were:

1. Review the existing literature and refine the aim to address research gaps within the available cycling literature relating to barriers and attractors to broader participation in utility cycling.
2. Develop a research plan based on the identified research gap which can add to the body of existing knowledge and provide outputs which are useful in informing policy.
3. Carry out exploratory and pilot research to refine the tools and methods ensuring that the chosen methods are appropriate and suitable for achieving the research aim.
4. Analyse and interpret the data obtained through the research in line with the research plan and taking account of the similarities and differences compared to previous research and ensuring that the views of those that currently do not cycle are considered.
5. Reflect on the findings of the research considering their implication for both research and policy.
6. Present policy and future research recommendations relating to the impact of perceptions and attitudes on cycling behaviour based on the outcome of the analysis

The literature review set out in Objective 1 is addressed in Chapter 2. Through this the research gap was identified leading to Objective 2, which is also addressed within Chapter 2. The exploratory and pilot research required for Objective 3 is addressed within Chapter 3, as is the data collection element of Objective 4. The analysis element is addressed in Chapters 4, 5 and 6. Chapter 7 brings together and interprets these findings to address Objective 5 and this chapter concludes with initial recommendations for policy measures and future research based on the outcome of the analysis as set out in Objective 6.

7.1 Findings from Attitudinal Analysis Results

There were 3807 valid responses to the survey, of which 1964 were Lower Band respondents. The relatively large sample size, with the capacity to break the respondents down by subgroup (such as gender or cycling frequency) together with the possibility of combining individual level measures of hard factors with responses to a range attitudinal statements has produced a useful dataset. Other studies have not combined this level of detail with a sample of this size (see Literature Review: Chapter 2).

The results of the attitudinal analysis highlighted the difference between the main sub-groups of interest within this research through the comparison across cycling levels and by gender. A consistent pattern across almost all of these statements was that male respondents and frequent cyclists had the most positive perceptions and female respondents and non-cyclists had the least positive. Where gender groups were compared within cycling levels, this pattern was also found and was particularly stark for areas which related to Perceived Behavioural Control, Safety and the Perception of Others. This fits well with literature findings, which suggest that some groups, including women, were more sensitive to what they perceived as being poor cycling environments (Ma and Dill, 2016). A recent systematic review (Aldred, Elliott et al., 2016) found strong evidence that women reported stronger preferences than men for segregated cycling infrastructure. However, the authors also concluded that no group preferred infrastructure which required sharing road space with motor traffic. The review also found weaker evidence of a stronger preference among older individuals for segregated infrastructure. Caulfield, Brick and McCarthy (2012) found that facilities that were segregated from traffic were preferred by cyclists at all levels of cycling confidence.

The statements relating to safety elicited strong responses. Lower Band respondents and female respondents appeared to respond particularly to these statements, but there were strong negative responses from all groups (Section 5.3.2). This suggests that this is an important issue which may be a significant barrier to cycling. The negative responses of Upper Band respondents suggests they are cycling despite their concerns about safety. The concerns of groups that might be considered "interested but concerned" about safety is a repeated theme in the literature but the findings here tend to suggest that very few respondents might be considered "strong and fearless". This is in line with <1% reported within the 4 types proposes by Geller (Geller, 2006; Dill and McNeil, 2013) however, within this study this group was not revealed as a segment within the analysis.

Attitudinal statements were chosen to elicit attitudes and perceptions relating to Hard Factors and Soft Factors as this was seen to be the most accessible method, particularly important for non-cyclists due to their lower level of knowledge of the issues compared to cyclists. Generally the use of attitudinal statements worked well with Chapter 5 demonstrating the differences between sub-groups across a wide range of issues. However, the statements which focused on more specific elements of the cycling environment (such as the disruption caused by poorly placed street furniture to cycling journeys) elicited a larger proportion of neutral responses from non-cyclists. This partially justifies the decision to use a relatively simple direct method over an indirect method (such as WTP) as the latter would have required non-cyclists to make a complex set of trade-offs among statements, including many on which they had little experience, and so may have increased the proportion of neutral responses still further (Krosnick et al., 2002). On the other hand, this also suggests that these statements used in this research may not have been the most effective way of electing responses on these issues. Two alternative approaches would have been to use images to help respondents picture the situation or to focus only on the statements which require less direct experience of cycling (such as S32 'The cycle routes in my area are well joined up' and S33 'There are lots of cycle routes where I live') as these seem to have been more successful, with a lower proportion of neutral responses, within this questionnaire. On the other hand, this may also have led to the analysis to neglect of important aspects of the infrastructure such as S29.

7.2 Findings from PLS-SEM Results

A comparison of the models for the Upper Band and Lower Band shows that there are some statistically significant differences between the groups. In the Lower Band model a change in the *Intention to Cycle* target variable can be seen to represent a change within the Stages of Change from precontemplation to contemplation and, in a few cases, action (Section 6.4). For these respondents the most important variable is *Positive Attitudes Towards Cycling* while *Perceived Behavioural Control* also has a relatively high path coefficient, which may indicate that some non-cyclists do not contemplate making trips by bicycle because they feel they would not be comfortable within the current environment. On the other hand, for the Upper Band a change in the *Intention to Cycle* target variables indicates that they are moving from making occasional recreational or utility journeys to making regular utility journeys by bicycle. The performance of the model is better for this group, indicating that the constructs contained within this model may be more relevant to those that are already cycling and that the Stages of Change scale differentiates effectively between different levels of cycling.

For the Upper Band respondents the *Convenience of Cycling* construct has the highest path coefficient. The importance of *Positive Attitudes* decreases for this group in comparison with the Lower Band model. This construct is still important when looking at the cross-sectional sample as a whole, indicating that, while attitudes are important in deciding to cycle, they do not appear to be so important in increasing the frequency of cycling. This finding supports research which has suggested that the reasons for starting to cycle are different to the reasons for increasing the frequency of cycling (Prins et al., 2016).

The perception of *Coherence and Directness* and *Feeling Comfortable* are significantly associated with the overall *Journey Quality*. The path coefficients for *Infrastructure Density* and *Journey Quality* within the Upper Band, Lower Band and full dataset models are relatively low (Table 6.7). Nevertheless, the REBUS analysis highlights differences between segments within the data (Section 6.4.2). This analysis revealed four segments in the data which can be related to Geller's 'four types of cyclists' (Geller, 2006; Dill and McNeil, 2013). The largest class which emerged from the analysis was 'No Way No How (Almost)' (33%) and the remainder of the dataset divided into two segments which could be considered to fall within the 'Interested but Concerned' category found with Geller's model and a final segment similar to the 'Enthused and Confident' classification. This analysis highlighted that the *Infrastructure Density* and *Journey Quality* constructs were more important for some segments than for the initial groupings based on cycling frequency.

Ma and Dill (2016) found that, despite general agreement between perceived and objective measures of the bicycle environment, older adults, and women with children were among the groups which perceived environments which may be 'objectively' cyclable as poor cycling environments. This aligns with the comparison of male with female Upper Band respondents and younger with older Upper Band cyclists (Section 6.4.3) which found that *Journey Quality* demonstrated significantly higher path coefficients for female and older cyclists. However, the comparison by gender also found a higher path coefficient relating to the link between *Infrastructure Density* and *Intention to Cycle* suggesting that the objective cycling environment is also important.

The use of double-barreled questions dealing with comfort and simplicity was dealt with in Section 5.3.1. While it should be acknowledged that these questions could be improved, they did not produce a pattern of responses that was out of line with others in the survey. A future study which improved this section of the survey may allow for the intended groupings based on the CROW guidance to be modelled successfully. The use of a use a wider range of indicator statements which reduced the need for a double-barreled construction to form the *Journey Quality* may resolve this issue.

The final model worked well for Upper Band respondents, but less well for Lower Band. This may be because that both the structural and measurement models were substantially based on the literature, which is itself largely based on studies of cyclists. Thus, it may be that major issues which influence the decision processes of non-cyclists are not included within this model. Although this study has been able to access views from more non-cyclists than many other studies in this field, it is still necessary to gain further information about this group of potential cyclists, to better understand the reasons behind their decision not to be current cyclists. This is especially important to inform policy development as these are the very people towards whom these policies should be targeted. Given the difficulties in reaching this group it may be useful to use traditional qualitative methods and carefully designed sampling techniques for 'hard to reach groups' (Shaghaghi, Bhopal and Sheikh, 2011).

7.2.1 *PLS-SEM and CB-SEM*

Whilst CB-SEM has been used in cycling research (Passafaro et al., 2014; Lois, Moriano and Rondinella, 2015), to the author's knowledge, there are currently no published applications of PLS-SEM to cycling-specific research. Thus the methodological choice adds novelty to this study. While the use of CB-SEM to explore the factors which influence the Intention to Cycle through the framework of the Theory of Planned Behaviour TPB have demonstrated that SEM can provide useful insights into the *Intention to Cycle*, the models have generally been applied at an aggregate level, with limited comparison of subgroups within the population of interest and the lack of an objective measure of the cycling environment. Therefore, further work was required to investigate how the relative importance of Hard and Soft Factors varies between identifiable sub-groups and segments within the data.

An important advantage of PLS-SEM is the suggestion that PLS-SEM allows for the retention of a greater number of indicator variables, boosting Content Validity. This benefit was demonstrated in the recent comparison of PLS and CB-SEM methods (Sarstedt, Hair et al., 2016) and is particularly relevant for this study as some of the constructs included in the final model (Section 6.4) retained only a small number of constructs.

Additionally, the same guidance (Hair, Mult et al., 2014) recommends PLS-SEM for cases with small sample sizes (n <200). This is of significance in this work for subgroups, for example the smallest group which arose from the REBUS analysis with four groups consisted of 261 respondents; using CB-SEM would have restricted the ability to work with groups of this size.

Of the two, CB-SEM is more widely applied and is suitable for factor based models (Hair, Mult et al., 2014), while PLS-SEM allows the estimation of composite based models and has been chosen:

i By researchers working with smaller datasets (Hair, Mult et al., 2014).

ii Where the data does not meet the requirements of CB-SEM (Rigdon, 2016).

iii Where the researcher wishes to use component based constructs (Henseler, Hubona and Ray, 2016).

iv Where the researcher cannot be sure whether the constructs are truly component or factor based (Sarstedt, Hair et al., 2016).

While it has been reported that a known weakness of PLS-SEM is the increased likelihood of bias within the results which can lead to an underestimation of the path coefficients and an overestimation of the variable loadings (Rönkkö and Evermann, 2013; Henseler, Hubona and Ray, 2016; Rönkkö, McIntosh et al., 2016), consensus has not yet developed on this issue. Some authors advise against the use of PLS-SEM until further work is done to establish the extent of issues such as the potential for bias (Rönkkö, McIntosh et al., 2016). Others argue that, while there is still work to be done around PLS-SEM, there are also issues with the alternatives (including CB-SEM) and continue to recommend PLS-SEM (Sarstedt, Hair et al., 2016). These authors conclude that PLS- SEM remains the most appropriate approach in cases such as those where the researcher does not know whether the constructs included in the model represent factors or composites. This recommendation is judged to apply to the current work as the model which is tested here involves measures of perceptions of the cycling environment and infrastructure density which are not known to be underlying factors.

The impact of underestimation of the path coefficients and an overestimation of the variable loadings may have led to lower path coefficients being found within this study than may be found by analysing this data through another method. This may happen;

1. directly through the underestimation of the path coefficient; and
2. indirectly through the retention of surplus indicators due to the overestimation of their variable loading which then reduce the path coefficient

This could have affect the results in this work in the following ways:

1. The highest path coefficient linking to the *Intention to Cycle*, within the main subsets, is 0.29 for *Convenience* when looking at Upper Band cyclists (see Table 6.7). Underestimation may have masked higher levels which may otherwise have helped highlight important issues and to improve the goodness of fit, which is partly based on the path coefficients.
2. The Subjective Norm wasn't significant, but was retained for content validity (Section 6.3.4) due to its presence within the core Theory of Planned Behaviour Model (Ajzen, 1991). It is lower than in some other studies which use SEM (Lois, Moriano and Rondinella, 2015) and this might also be due to this issue with underestimation in PLS-SEM.
3. The Safety construct was removed from the model as bootstrap analysis did not find that the strength of its path coefficient linking to *Journey Quality* was significantly different to 0 (Section 6.4). If this has been underestimated it may otherwise have been retained using another method.
4. Within the PLS-MGA analysis some p-values, such as when looking at the path coefficient between *Infrastructure Density* and *Intention to Cycle* for Upper Band Cyclists and comparing by gender, were found to just fall short of 0.05 (Section 6.4.3). This difference may be more or less significant depending on the impact of any underestimation.

Reviewing the methodological choice at this stage, it is useful to note the recent developments within SEM. A commonly stated weakness of PLS-SEM is that reciprocal relationships cannot be modelled (Hair, Mult et al., 2014), recent developments have shown promise in allowing recursive relationships to be included (Henseler, Hubona and Ray, 2016). Also, other techniques, such as Generalised Least Squares - Structural Equation Modelling (GLS-SEM), are now claimed to be more able to cope with non-normal data than previous non PLS-SEM methods (Hancock and Mueller, 2013) while retaining the advantages of the more widely applied CB-SEM. However, one drawback of the GLS estimator is that it does require larger sample sizes than PLS-SEM and thus would still restrict the potential for the analysis of sub-groups which was important to achieve the aim of this research.

7.3 Bringing the strands of analysis together

While the analysis of the attitudinal statements within Chapter 5 and PLS-SEM analysis in Chapter 6 are useful separately, it is important to consider them together in order to develop a rounded understanding of the issues.

7.3.1 *Safety*

Within previous research, perceived safety appears to play an important role in the decision to cycle and in cycling frequency (Aldred, Elliott et al., 2016). The issue of perceived safety is reflected differently in Chapters 5 and 6. Within chapter 5 the *Safety* construct is not included in the final version of the PLS model as the strength of the path-coefficient between it and the *Journey Quality* and *Intention to Cycle* constructs were not significant (Section 6.4). However, within the attitudinal analysis it is clear that the statements relating to safety elicit strong responses which suggests that this is an important issue which may be a significant barrier to cycling (Section 5.3.2).

This may seem contradictory but it stems from the purpose of approaches such as PLS-SEM which is to investigate the variables which explain the variance between individual elements within the dataset. As respondents from across the spectrum of cycling frequency, from non-cyclist to frequent cyclist, agree that the cycling environment is unsafe the Safety construct does not explain the variance, and as thus has a low value for the path coefficient. Instead the constructs which allow the cyclists to overcome this barrier (i.e. *Perceived Behavioural Control*) or those which encourage them to cycle despite their poor perception of the safety (i.e. *Convenience of Cycling*) are highlighted. In this context the negative path coefficients found within the REBUS analysis also support the finding that many cyclists seem to be cycling despite a perception that the local environment is unsafe. There are two main factors which are to be considered here and which interlink. These are

1. The perceived safety of different types of infrastructure.
2. The individual's tolerance of and confidence in using that infrastructure.

For example both a confident cyclist and a novice cyclist may regard cycling on the road with traffic as unsafe, but the confident cyclist may be more tolerant of that infrastructure because of their greater confidence on a bike or lower aversion to risk.

Within Chapter 6, subgroup analysis revealed interesting differences between older and younger respondents relating to the strength of the association between *Journey Quality* and the *Intention to Cycle*. This is an area where there have been recent calls for an improved evidence base relating to the concerns of older cyclists (Aldred, Elliott et al., 2016).

7.3.2 *Subjective Norm*

The Subjective Norm appears to have surprisingly little influence within this analysis compared to some previous research (Passafaro et al., 2014) which looks at cycling as a mode choice, however, this is not unusual within research which uses the Theory of Planned Behaviour (Armitage and Conner, 2001). This can be put in context through consideration of the results from Chapter 4. These results highlighted that female non-cyclists were the least likely to feel that others would approve or had encouraged them to cycle.

Alongside this, female respondents were also more likely to agree that they were not the type of person that rides a bike. This aligns with a developing research area suggesting that identity plays a previously underestimated role in our travel behaviour (Lois, Moriano and Rondinella, 2015; Heinen, 2016; Füssl and Haupt, 2017) found that subjective norms had a subjective norm in some or all situations depending on the research context. Lois, Moriano and Rondinella (2015) found identity was more predictive when used within a SEM model based on the Theory of Planned Behaviour. Gatersleben and Haddad (2010) reported intentions to use a bicycle in the future were positively related to perceptions of the typical bicyclist as a commuter or 'Hippy-go-lucky' bicyclist.

This importance can be interpreted in two ways, either it may be an area on which soft measures can focus to attract those that already align with aspects of cycling sub-cultures, or it is something that should be mainstreamed, taking the specific 'identity of a cyclist' away and becoming more of a cultural norm. Given (i) that non-cyclists were less likely to agree that they were motivated to cycle because it is good for the environment (Section 5.4.1) (ii) the issues with focusing on the commute (Eyer and Ferreira, 2015), (iii) the success of cycling in the countries such as the Netherlands and Denmark, where cycling is not something that people feel forms their identity (Heinen, Maat and van Wee, 2011), suggests that the latter may be a more fruitful approach. Supporting the argument for broadening the appeal by making cycling seem normal, Gatersleben and Appleton (2007) found that many non-cyclists, (especially women) thought of cycling as "something other people do". One interpretation of this could be that appealing to niche images (such as 'Hippy go Lucky' or 'MAMIL') within the overall population could further exacerbate this issue.

7.4 Conclusion

The aim of this thesis was to add to the existing knowledge base on the impact of attitudes and perceptions on the intention to cycle for utility purposes and through this inform policy decisions to enable a broader population to cycle for utility purposes than is currently found in countries with low cycling mode shares, such as the UK. This follows from the suggestion within previous research that a broad population engaged in utility cycling is necessary to increase cycling levels substantially and maximise the benefits to society, the environment and individuals (Cavill Adrian and England, 2007; Fraser and Lock, 2011).

One of the main differences between countries with high and low levels of cycling is the rate of female participation in cycling (see Section 1.3) with levels close to gender balance in countries such as Denmark and the Netherlands. In this context the findings detailed in Chapter 5, which show that female respondents had a poorer perception of the cycling environment and confidence cycling with traffic than male respondents, are important. While differences in the strength of preferences for segregated infrastructure are well established in the literature (Aldred, Elliott et al., 2016) these findings add to the existing research base in two main ways.

Firstly, the previous research has focused mainly on the preferences and experiences of existing cyclists (Aldred, 2013; Willis, Manaugh and El-Geneidy, 2015). Through the collection and analysis of data from a large sample of both cyclists and non-cyclists, this research suggests that the differences hold across different levels of cycling. This is important as any policies intended to increase levels of utility cycling must necessarily consider the views of those who currently do not cycle.

Secondly, through the analysis of a broad range of qualitative issues (from perceptions of the safety of the cycling environment, workplace facilities and attitudes towards cycling) this research shows that these differences are not restricted to preferences for segregated infrastructure, with female non-cyclists consistently reporting the least positive perceptions of all the issues considered. This highlights the need to address wider societal issues which negatively impact female participation in cycling alongside the installation of cycling infrastructure in order to enable a broader population to cycle.

Another contribution of this research is the combination of an objective measure of the cycling infrastructure in a respondent's local area (represented through density of cycle lanes) alongside attitudinal statements and perceptions of the cycling environment at a national level. This builds on previous research using the socio-ecological approach to study cycling where perceptions and objective measures have been combined within limited geographies (Handy, Xing and Buehler, 2010) . It also extends the findings of other studies in which perceptions were not incorporated (Madsen, 2013) and supports their findings that there is a significant link between objective measures of the cycling environment and cycling.

Within the PLS-SEM analysis (see Chapter 6 this showed a small but significant relationship between the density of cycle lanes and the intention to cycle. When considered alongside the strong link between the perceived convenience of cycling and the intention to cycle, this highlights the importance of providing routes for cyclists which are both safe and convenient. While safety is often the main topic when cycling is discussed in research or policy, these results support a greater consideration of convenience.

The application of PLS-SEM using a relatively large sample also provides a contribution to the application of SEM methods to cycling research. Previous research has applied CB-SEM methods with smaller sample sizes (Lois, Moriano and Rondinella, 2015; Muñoz, Monzon and López, 2016). As such this research tests the suitability of the PLS approach and, through the successful modelling of non-normal data, highlights the need to consider methods (such as GLS-SEM) which allow for non-normal data to be modelled while maintaining benefits of CB-SEM as discussed in Section 7.2.1.

The application of PLS-SEM allowed for underlying groups within the data to be identified using REBUS with four classes identified which build on those proposed by Geller (2006). The concerns of groups that are considered in both typologies to be "interested but concerned" about safety is a repeated theme in the literature. The categorisation produced in this study through REBUS analysis separates out those that are 'interested but concerned' from 'concerned cyclists' highlighting that many existing cyclists may be cycling despite their concerns rather than because of their positive perceptions. This can be seen in both the results of the attitudinal analysis (see Chapter 5 and PLS-SEM (see Chapter 6). This triangulation highlights the benefits of combining these methods, allowing for more strength in this conclusion.

7.5 Policy recommendations

1. Safety is a barrier to all and cyclists cycle despite of a low perception of safety, not because of a high level. Research shows that women and older cyclists who are underrepresented in UK cycling population have stronger preferences for segregated infrastructure. This research adds to the weight of that evidence with both perceived and actual infrastructure being more important to females and older individuals
2. Convenience is the main reason that existing cyclists cycle. When planning new developments and transport infrastructure convenient as well as safe options must be a priority
3. Women are particularly likely to see cycling as something that they don't do. Cycling should be normalised, moving away from images of cyclists who are a danger to others/hippies.
4. Despite growing body of evidence some areas still require additional evidence, while this is partly covered by academic research recommendations it is also important to have evidence of the impact of cycling interventions considered when planning policies or interventions. UK evidence on the impacts of policies and especially network effects is still limited.

These policy recommendations can be epitomised by the recommendations of Nobel-Prize winning economist Richard Thaler to Prime Minister David Cameron in 2009 (Sunstein, 2015).

"Thaler emphasized two simple ideas, which have become mantras for the team. The first: ’If you want to encourage someone to do something, make it easy.’ The second: ’We can’t do evidence-based policy without evidence.’"

7.6 Recommendations for further research

This research has attempted to address the research gap identified in Section 2.6 through the collection of a large dataset containing the attitudes and perceptions of cyclists and non-cyclists and the application of descriptive analysis and the development theory-led PLS-SEM model, combining this data with an objective measure of the cycling environment.

The results which have emerged from this research add to the existing research base by elucidating the difference between the importance of safety to both cyclists and non-cyclists and its lack of ability to explain the variance between the two sets and providing further evidence of the importance of attitudes in encouraging the contemplation of utility and perceived convenience in increasing the level of cycling for utility trips.

Alongside other recent research this study can be used to identify the priority areas for further research. In a substantial review of cycling research Buehler and Dill (2015) observed that, although there has been a significant increase in research linking bikeway infrastructure and cycling levels since 2010, more empirical studies using comprehensive network measures are required. Data in this thesis has included respondents’ attitudes relating to a wide range of aspects of the cycling infrastructure (based on the literature and focus groups) and also includes a simple measure of cycling infrastructure experienced by each respondent (infrastructure density). However, it does not attempt to obtain objective data on the impact of specific facility designs and new types of facilities that are called for by Buehler and Dill. Thus, further work of the type they suggest, is recommended.

1. More studies should be directed at non-cyclists who don’t consider themselves potential cyclists in order to establish a theoretical model and bank of potential indicators which better fits their perceived barriers and attractors to cycling. Grounded Theory may be an appropriate approach for this exploratory work.

2. The infrastructure density measurement within this research did not include a measure to differentiate between high and low quality infrastructure, developments with cyclestreets may allow this to be done on a large scale, LCDS may allow this at more detailed local levels.
3. Developments in GLS-SEM methods may allow for the benefits of CB-SEM to be retained while also not imposing distributional assumptions on the data.
4. Further work to explore differences by ethnicity which was not possible from the dataset collected for this study.
5. Develop a robust survey instrument that can be used with cyclists and non-cyclists in a variety environments, including those with access to a well-developed infrastructure and those without.
6. Access panel based work that opens up the potential for multi-national studies combining the same survey and measure of cycling infrastructure to obtain directly comparable results from areas with different cycling cultures and policies.

Appendix A. Questionnaire for Main Survey as Appendix

The questionnaire used within the main study is reproduced on the following pages.

Screener Questions

What is your age?*

____

What is your gender?*

( ) Male

( ) Female

Which region do you live in?*

( ) England – North East England

( ) England – North West England

( ) England – Yorkshire and the Humber

( ) England – East Midlands

( ) England – West Midlands

( ) England – East of England

( ) England – Greater London

( ) England – South East England

( ) England – South West England

( ) Scotland

( ) Wales

( ) Northern Ireland

( ) The Channel Islands

( ) Other Region - Write In: ____

How often do you cycle (for any purpose) during October - February?*

( ) At least once a day

( ) Less than once a day, but at least 3 times a week

( ) Once or twice a week

( ) Less than that but more than twice a month

( ) Once or twice a month

( ) Less than that but more than twice a year

( ) Once or twice a year

( ) Less than that or never

How often do you cycle (for any purpose) during March - September?*

( ) At least once a day

( ) Less than once a day, but at least 3 times a week

( ) Once or twice a week

( ) Less than that but more than twice a month

( ) Once or twice a month

( ) Less than that but more than twice a year

( ) Once or twice a year

( ) Less than that or never

Thinking about the trips that you make between October and February what proportion of them are for leisure? *

( ) None

( ) Almost none

( ) Less than half

( ) Around half

( ) More than half

( ) Almost all

( ) All

( ) Not applicable

Thinking about the trips that you make between March and September what proportion of them are for leisure? *

( ) None

( ) Almost none

( ) Less than half

( ) Around half

( ) More than half

( ) Almost all

( ) All

( ) Not applicable

Main Survey

Hello!

Thank you for your interest in this survey which is being distributed as part of a research project at the Transport Operations Research Group, Newcastle University. The purpose of this research is to get a better picture of people's views on cycling infrastructure in their area and on how cycling could/does fit into their day-to-day routine. You have been selected to complete the survey as we are interested in hearing the opinions of people like you.

This survey should take around 10 minutes to complete and we really appreciate your participation. At the end of the survey you will be automatically redirected back to mingle.
Consent

Before you start the survey please take the time to read the following important information. The survey procedure consists of completing an online questionnaire. Your responses will be confidential and we do not ask for your name, phone number, email or postal address. The survey questions will be about you, your household, your work and your views on cycling. Your data will be stored in accordance with the Data Protection Act 1998. All data is stored in a password protected electronic format. The data collected will be anonymised and used for scholarly purposes only. The findings will be used in academic publications. This research has received funding from the Engineering and Physical Sciences Research Council (EPSRC) and Department for Transport. Your data will not be shared outside of the project and will not be sold.

ELECTRONIC CONSENT:
Clicking on the agree button and then continuing with the survey indicates that:
You have read the above information
You voluntarily agree to participate
You are at least 18 years of age*

( ) Agree

( ) Disagree

What is your ethnic group?*

( ) White - English/Welsh/Scottish/Northern Irish/British

( ) White - Irish

( ) White - Gypsy or Irish Traveller

( ) White - Any other White background, please describe

( ) Mixed - White and Black Caribbean

( ) Mixed - White and Black African

( ) Mixed - White and Asian

( ) Mixed - Any other Mixed/Multiple ethnic background

( ) Asian/Asian British - Indian

( ) Asian/Asian British - Pakistani

( ) Asian/Asian British - Bangladeshi

( ) Asian/Asian British - Chinese

( ) Asian/Asian British - Any other Asian background, please describe

( ) Black/African/Caribbean/Black British - African

( ) Black/African/Caribbean/Black British – Caribbean

( ) Any other Black/African/Caribbean background

( ) Arab

( ) Other - Write In: ____

Which of these best describes the area in which you live?*

( ) Urban

( ) Suburban

( ) Rural

( ) Other - Write In: ____

What is the first part of your postcode (e.g. for NW1 for NW1 5RU)*

____

Do any children aged 16 or under normally live at home with you?*

( ) Yes

( ) No

( ) Prefer not to say

During the last week, how many hours did you spend on each of the following activities?*

	None	**Some, but less than 1 hour**	**Between 1 and 3 hours**	**More than 3 hours**
Physical exercise such as swimming, jogging, aerobics, football, tennis, gym workout, etc. but not cycling or walking	( )	( )	( )	( )
Cycling (including cycling to work) and during leisure time	( )	( )	( )	( )
Walking, including walking to work, shopping, for pleasure etc.	( )	( )	( )	( )
Housework or childcare (removed from Wave 2)	( )	( )	( )	( )
Gardening or DIY (removed from Wave 2)	( )	( )	( )	( )

Do you have any disability or other long standing health issue that makes it hard for you to do any of the following? (please select all that apply)*

[ ] Go out on foot

[ ] Use local buses

[ ] Get in or out of a car

[ ] Use a bicycle

[ ] None of these

[ ] Prefer not to say

How would you describe your usual walking pace?* (removed from Wave 2)

( ) Slow pace

( ) Steady, average pace

( ) Brisk pace

( ) Fast pace

( ) I am unable to walk for sustained periods

( ) Prefer not to say

What is the highest qualification that you have completed*

( ) University Degree or above

( ) Diploma in Higher Education, A-Level - or equivalent

( ) GCSE or equivalent

( ) None of the above

( ) Prefer not to say

Logic: Show/hide trigger exists.

Which of these best describe your employment status?*

( ) Working full time (30 hours or more a week)

( ) Working part time (Less than 30 hours a week)

( ) Unemployed and looking for work

( ) In education

( ) Looking after family or home

( ) Unemployed and not seeking work

( ) Retired

( ) None of the above

( ) Prefer not to say

Logic: Show/hide trigger exists. Hidden unless: #10 Question "Which of these best describe your employment status?" is one of the following answers ("Working full time (30 hours or more a week)","Working part time (Less than 30 hours a week)")

Do you work as an employee or are you self-employed?*

( ) Employee

( ) Self-employed with employees

( ) Self-employed/freelance without employees

( ) None of the above

( ) Prefer not to say

Logic: Hidden unless: #11 Question "Do you work as an employee or are you self-employed?" is one of the following answers ("Employee")

How many people work for your employer at the place where you work?*

( ) 1-24

( ) 25 - 99

( ) 100 or more

( ) Don't know

Logic: Hidden unless: #11 Question "Do you work as an employee or are you self-employed?" is one of the following answers ("Employee")

Do you supervise any other employees?' (A supervisor or foreman is responsible for overseeing the work of other employees on a day-to-day basis)*

( ) Yes

( ) No

( ) Don't know

( ) Prefer not to say

Logic: Hidden unless: #11 Question "Do you work as an employee or are you self-employed?" is one of the following answers ("Self-employed with employees")

How many people do you employ?*

( ) 1-24

( ) 25 -99

( ) 100 or more

( ) Prefer not to say

Logic: Hidden unless: #10 Question "Which of these best describe your employment status?" is one of the following answers ("Working full time (30 hours or more a week)","Working part time (Less than 30 hours a week)")

Which of the options listed below best describes your current employment?*

( ) **Modern professional occupations** e.g. Teacher, nurse, police officer (sergeant or above), software designer

( ) **Clerical and intermediate occupations** e.g. Secretary, personal assistant, clerical worker, call centre agent

( ) **Senior managers or administrators** e.g. finance manager or chief executive

( ) **Technical and craft occupations** e.g. Motor mechanic, plumber, gardener, train driver

( ) **Semi-routine manual and service occupations** e.g. Postal worker, machine operative, security guard, caretaker, farm worker, receptionist or sales assistant

( ) **Routine manual and service occupations** e.g. HGV driver, cleaner, labourer, waiter/waitress or bar staff

( ) **Middle or junior managers** e.g. Office manager, retail manager, bank manager, restaurant manager, warehouse manager, publican

( ) **Traditional professional occupations** e.g. Accountant, solicitor, medical practitioner, civil/mechanical engineer

Logic: Hidden unless: #10 Question "Which of these best describe your employment status?" is one of the following answers ("Working full time (30 hours or more a week)","Working part time (Less than 30 hours a week)","In education")

Please tell us the type and amount of physical activity involved in your work or study.*

( ) I spend most of my time at work sitting (such as in an office)

( ) I spend most of my time at work standing or walking. However, my work does not require much intense physical effort (e.g. shop assistant, hairdresser, security guard, childminder, etc.)

( ) My work involves definite physical effort including handling of heavy objects and use of tools (e.g. plumber, electrician,carpenter, cleaner, hospital nurse, gardener, postal delivery workers etc.)

( ) My work involves vigorous physical activity including handling of very heavy objects (e.g. scaffolder, construction worker, refuse collector, etc.)

Logic: Show/hide trigger exists. Hidden unless: #10 Question "Which of these best describe your employment status?" is one of the following answers ("Working full time (30 hours or more a week)","Working part time (Less than 30 hours a week)","In education")

Approximately how far do you live from your place of work or study?*

( ) Work mainly from home

( ) No usual place of work or study

( ) Less than 2 miles

( ) 2 to less than 5 miles

( ) 5 to less than 10 miles

( ) 10 miles or more

( ) Don’t know

Logic: Hidden unless: #17 Question "Approximately how far do you live from your place of work or study?" is one of the following answers ("Less than 2 miles","2 to less than 5 miles","5 to less than 10 miles","10 miles or more","Don’t know")

What time do you usually start your journey to work or study?*

( ) No usual time
( ) 06:00 - 06:29
( ) 06:30 - 06:59
( ) 07:00 - 07:29
( ) 07:30 - 07:59
( ) 08:00 - 08:29
( ) 08:30 - 08:59
( ) 09:00 - 09:29
( ) 09:30 - 09:59
( ) 10:00 - 10:29
( ) 10:30 - 10:59
( ) 11:00 - 11:29
( ) 11:30 - 11:59
( ) 12:00 - 12:29
( ) 12:30 - 12:59
( ) 13:00 - 13:29
( ) 13:30 - 13:59
( ) 14:00 - 14:29
( ) 14:30 - 14:59
( ) 15:00 - 15:29
( ) 15:30 - 15:59
( ) 16:00 - 16:29
( ) 16:30 - 16:59
( ) 17:00 - 17:29
( ) 17:30 - 17:59
( ) 18:00 - 18:29
( ) 18:30 - 18:59
( ) 19:00 - 19:29
( ) 19:30 - 19:59
( ) 20:00 - 20:29
( ) 20:30 - 20:59
( ) 21:00 - 21:29
( ) 21:30 - 21:59
( ) 22:00 - 22:29
( ) 22:30 - 22:59
( ) 23:00 - 23:29
( ) 23:30 - 23:59
( ) 00:00 - 00:29
( ) 00:30 - 00:59
( ) 01:00 - 01:29
( ) 01:30 - 01:59
( ) 02:00 - 02:29
( ) 02:30 - 02:59
( ) 03:00 - 03:29
( ) 03:30 - 03:59
( ) 04:00 - 04:29
( ) 04:30 - 04:59
( ) 05:00 - 05:29
( ) 05:30 - 05:59

Logic: Hidden unless: (#10 Question "Which of these best describe your employment status?" is one of the following answers ("Working full time (30 hours or more a week)","Working part time (Less than 30 hours a week)","In education") AND #17 Question "Approximately how far do you live from your place of work or study?" is one of the following answers ("Less than 2 miles","2 to less than 5 miles","5 to less than 10 miles","10 miles or more","Don't know"))

Thinking about your work and the cycling facilities at your place of work or study please indicate how strongly you agree or disagree with these statements*

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
My place of work/study has good shower /changing facilities	( )	( )	( )	( )	( )	( )	( )
My place of work/study has good bike parking	( )	( )	( )	( )	( )	( )	( )
My place of work/study encourages people to cycle	( )	( )	( )	( )	( )	( )	( )
I would be happy to shower and change clothes at work after cycling into work/study if the facilities were good	( )	( )	( )	( )	( )	( )	( )
I often have to carry equipment for my work which is heavy	( )	( )	( )	( )	( )	( )	( )
I often have to travel during my working day (e.g. between sites or to visit clients)	( )	( )	( )	( )	( )	( )	( )

Do you currently hold a valid driving licence?*

( ) Yes

( ) No

How often do you travel (for any purpose) by...*

	At least once a day	Less than once a day, but at least 3 times a week	Once or twice a week	Less than that but more than twice a month	Once or twice a month	Less than that but more than twice a year	Once or twice a year	Less than that or never
Car, as a driver	( )	( )	( )	( )	( )	( )	( )	( )
Car, as a passenger	( )	( )	( )	( )	( )	( )	( )	( )
Local public transport (e.g. bus or tram)	( )	( )	( )	( )	( )	( )	( )	( )
Long distance public transport (e.g. train or coach)	( )	( )	( )	( )	( )	( )	( )	( )
Walking	( )	( )	( )	( )	( )	( )	( )	( )

Logic: Hidden unless: Question "Car, as a driver" is one of the following answers ("At least once a day","Less than once a day, but at least 3 times a week","Once or twice a week","Less than that but more than twice a month","Once or twice a month")

Here are some statements people have made about driving, please indicate how strongly you agree or disagree with them on the scale provided*

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
For most journeys, I would rather use the car than any other form of transport	( )	( )	( )	( )	( )	( )	( )
I like to drive just for the fun of it	( )	( )	( )	( )	( )	( )	( )
I am not interested in reducing my car use	( )	( )	( )	( )	( )	( )	( )
Driving gives me a way to express myself	( )	( )	( )	( )	( )	( )	( )

How many cars/vans does your household own or have continuous use of at present?*

( ) None

( ) 1

( ) 2

( ) 3

( ) 4 or more

Excluding exercise bikes do you currently…*

[ ] Own a bicycle yourself

[ ] Sign up to a bike hire scheme (e.g. Satander Cycles, Bike & Go)

[ ] Access to pool bikes through work/study

[ ] Share a bicycle or have easy access to a bicycle owned by someone else

[ ] Have limited access to a bicycle owned by someone else

[ ] Have no access to a bicycle

Thinking about your everyday journeys (e.g. to work or the shops) which of these statements best applies to you?*

( ) I have not thought about making my everyday journeys by bicycle

( ) I never make my everyday journeys by bicycle, but sometimes consider it

( ) I sometimes make my everyday journeys by bicycle, but I am not thinking about doing so more regularly

( ) I sometimes make my everyday journeys by bicycle, and I am seriously thinking about doing so more regularly

( ) I have recently started making my everyday journeys by bicycle

( ) I have been making my everyday journeys by bicycle for some time and I plan to continue doing so

( ) I have been making my everyday journeys by bicycle for some time but would like to do so less regularly

( ) I used to make my everyday journeys by bicycle and would consider doing so again

( ) I used to make my everyday journeys by bicycle and would not consider doing so again

---

Thinking about if you were to make a journey by bike in your local area…

Where 0 = Not at all confident and 10 = Completely confident

Out of 10, how confident are you that your journey would be safe?*

( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10

Thinking about if you were to make a journey by bike in your local area…

Where 0 = Not at all confident and 10 = Completely confident

Out of 10, how confident are you that your journey would be comfortable and simple to make?*

( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10

Thinking about if a secondary school child (11-16 years old) were to make an unaccompanied journey by bike in your local area…

Where 0 = Not at all confident and 10 = Completely confident

Out of 10, how confident are you that their journey would be safe?*

( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10

Thinking about if a secondary school child (11-16 years old) were to make an unaccompanied journey by bike in your local area…

Where 0 = Not at all confident and 10 = Completely confident

Out of 10, how confident are you that their journey would be comfortable and simple for them to make?*

( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10

Here are some statements people have made about cycling. Thinking about how you feel about cycling in general please indicate how strongly you agree or disagree with them on the scale provided:*

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
I feel motivated to cycle/start cycling to improve my fitness	( )	( )	( )	( )	( )	( )	( )
I feel motivated to cycle/start cycling because it is good for the environment	( )	( )	( )	( )	( )	( )	( )
I feel motivated to cycle/start cycling to save money	( )	( )	( )	( )	( )	( )	( )
Many people I know cycle	( )	( )	( )	( )	( )	( )	( )
In general, I think successful people drive rather than cycle	( )	( )	( )	( )	( )	( )	( )
It's hard to look fashionable when cycling wearing a helmet	( )	( )	( )	( )	( )	( )	( )
Cycling is something I want to do	( )	( )	( )	( )	( )	( )	( )
I often have to travel with shopping which is heavy	( )	( )	( )	( )	( )	( )	( )
I am unable to cycle due to childcare commitments	( )	( )	( )	( )	( )	( )	( )

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
My day-to-day journeys are too long to cycle	( )	( )	( )	( )	( )	( )	( )
I am physically fit enough to cycle regularly	( )	( )	( )	( )	( )	( )	( )
Cycling is more convenient than driving	( )	( )	( )	( )	( )	( )	( )
Cycling provides people with freedom and independence	( )	( )	( )	( )	( )	( )	( )
The British weather puts me off cycling	( )	( )	( )	( )	( )	( )	( )
It would be easy for me to fit cycling into my home and work routine	( )	( )	( )	( )	( )	( )	( )
Cycling is fun	( )	( )	( )	( )	( )	( )	( )
I would be confident making minor repairs to a bicycle (e.g. a puncture)	( )	( )	( )	( )	( )	( )	( )
Cycling is more convenient than walking	( )	( )	( )	( )	( )	( )	( )
Cycling is more convenient than getting public transport	( )	( )	( )	( )	( )	( )	( )

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
My friends and family would/do worry about me getting hurt riding a bike	( )	( )	( )	( )	( )	( )	( )
I'm not the type of person that rides a bike	( )	( )	( )	( )	( )	( )	( )
I was encouraged to cycle when I was a child	( )	( )	( )	( )	( )	( )	( )
A large number of cyclists put themselves and others in danger	( )	( )	( )	( )	( )	( )	( )
My friends would approve if I rode a bike/do approve that I ride a bike (Added to Wave 2)	( )	( )	( )	( )	( )	( )	( )
My family would approve if I rode a bike/do approve that I ride a bike (Added to Wave 2)	( )	( )	( )	( )	( )	( )	( )

Here are some more statements people have made about cycling. Thinking about cycling in your local area please indicate how strongly you agree or disagree with them on the scale provided:

Where a cycle route is mentioned this refers to any space that has been allocated for cyclists. This could be an on road cycle lane designated by a painted line or an off road track shared with pedestrians or just for bikes. Please answer these questions based on your general impression of cycling in your local area.*

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
Poor quality surfaces on roads and cycle routes cause problems for cyclists in my area	( )	( )	( )	( )	( )	( )	( )
The cycle routes in my area are well cleared/gritted in winter	( )	( )	( )	( )	( )	( )	( )
The cycle routes in my area are attractive and well kept	( )	( )	( )	( )	( )	( )	( )
Cyclists are provided with sufficient protection at roundabouts	( )	( )	( )	( )	( )	( )	( )
Cycling journeys in my area are stop-start because cyclists are not given right of way	( )	( )	( )	( )	( )	( )	( )
It is clear where people are allowed to cycle and where they are not	( )	( )	( )	( )	( )	( )	( )
The cycle routes in my area are well joined up	( )	( )	( )	( )	( )	( )	( )
There are lots of cycle routes where I live	( )	( )	( )	( )	( )	( )	( )
Cyclists are protected on roads with fast moving traffic	( )	( )	( )	( )	( )	( )	( )

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
It is easy to find and follow a suitable route when cycling somewhere for the first time	( )	( )	( )	( )	( )	( )	( )
Car/van drivers give cyclists enough time and space	( )	( )	( )	( )	( )	( )	( )
Poorly placed street furniture/signs cause obstructions on cycle routes in my local area	( )	( )	( )	( )	( )	( )	( )
The cycle routes in my area protect cyclists from parked cars and opening car doors	( )	( )	( )	( )	( )	( )	( )
It is hard to cycle where I live because there are steep hills	( )	( )	( )	( )	( )	( )	( )
You are vulnerable to violent crime when cycling alone after dark	( )	( )	( )	( )	( )	( )	( )
The residential roads in my area are safe for cycling	( )	( )	( )	( )	( )	( )	( )
You are vulnerable to verbal abuse when cycling	( )	( )	( )	( )	( )	( )	( )

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
I have a good space to store a bike at home for day-to-day use	( )	( )	( )	( )	( )	( )	( )
It is easy to securely park your bike when out and about	( )	( )	( )	( )	( )	( )	( )
Cycling in my area is unpleasant due to traffic fumes	( )	( )	( )	( )	( )	( )	( )
I am confident sharing the road with traffic when cycling	( )	( )	( )	( )	( )	( )	( )
Bus/HGV drivers give cyclists enough time and space	( )	( )	( )	( )	( )	( )	( )
Cycling after dark is more dangerous because it is harder for drivers to see you	( )	( )	( )	( )	( )	( )	( )
Cyclists are provided with sufficient protection at junctions and when crossing side roads	( )	( )	( )	( )	( )	( )	( )

Page exit logic: Speeders**IF:** "Elapsed Survey Time" is less than "360" **THEN:** Disqualify and display: "Sorry, you do not qualify to take this survey." Redirect to: mingle.respondi.com/s/517887/ospe.php3?c_0002=3

Are there any other issues which affect your experience when cycling or choice not to cycle that have not been included in this survey?____

Thank You!

References

Ajzen, I. (1991). 'The Theory of Planned Behavior'. In: *Organizational Behavior and Human Decision Processes* 50, pp. 179–211.

Akar, G. and Clifton, K. (2009). 'Influence of Individual Perceptions and Bicycle Infrastructure on Decision to Bike'. In: *Transportation Research Record: Journal of the Transportation Research Board* 2140, pp. 165–172. DOI: 10.3141/2140-18.

Aldred, R. (2010). ''On the outside': constructing cycling citizenship'. In: *Social & Cultural Geography* 11.1, pp. 35–52. DOI: 10.1080/14649360903414593.

Aldred, R. (2012). *Cycling Cultures: Summary of key findings and recommendations*.

Aldred, R. (2013). 'Who are Londoners on bikes and what do they want? Negotiating identity and issue definition in a 'pop-up' cycle campaign'. In: *Journal of Transport Geography* 30, pp. 194–201. DOI: 10.1016/j.jtrangeo.2013.01.005.

Aldred, R. (2015). 'Adults' attitudes towards child cycling: a study of the impact of infrastructure'. In: *European Journal of Transport and Infrastructure Research* 15.2, pp. 92–115.

Aldred, R. and Crosweller, S. (2015). 'Investigating the rates and impacts of near misses and related incidents among UK cyclists'. In: *Journal of Transport & Health* 2.3, pp. 379–393. DOI: 10.1016/j.jth.2015.05.006.

Aldred, R. and Dales, J. (2017). 'Diversifying and normalising cycling in London, UK: An exploratory study on the influence of infrastructure'. In: *Journal of Transport & Health* 4, pp. 348–362. DOI: 10.1016/j.jth.2016.11.002.

Aldred, R., Elliott, B. et al. (2016). 'Cycling provision separated from motor traffic: a systematic review exploring whether stated preferences vary by gender and age'. In: *Transport Reviews*, pp. 1–27. DOI: 10.1080/01441647.2016.1200156.

Aldred, R. and Jungnickel, K. (2014). 'Why culture matters for transport policy: the case of cycling in the UK'. In: *Journal of Transport Geography* 34, pp. 78–87. DOI: 10.1016/j.jtrangeo.2013.11.004.

Aldred, R., Woodcock, J. and Goodman, A. (2015). 'Does More Cycling Mean More Diversity in Cycling?' In: *Transport Reviews*, pp. 1–17. DOI: 10.1080/01441647.2015.1014451.

Anable, J. and Wright, S. (2013). *Work Package 7 Golden Questions and Social Marketing Guidance Report*.

Armitage, C. J. and Conner, M. (2001). 'Efficacy of the Theory of Planned Behaviour: a meta-analytic review.' In: *Br J Soc Psychol* 40.4, pp. 471–499.

Avni, A. et al. (2015). *Literature Searches and Literature Reviews for Transportation Research Projects*. Washington, DC.

Bekkum, J. E. van, Williams, J. M. and Morris, P. G. (2011). 'Cycle commuting and perceptions of barriers: stages of change, gender and occupation'. In: *Health Education* 111.6, pp. 476–497. DOI: 10.1108/09654281111180472.

Ben-Akiva, M. et al. (1999). 'Integration of Choice and Latent Variable Models'. In: *Proceedings of the 8th International Conference on Travel Behavior, Austin, TX*.

Bilotkacha, V. and Mills, M. (2013). 'Economics of Electric Vehicle Adoption: A Framework Model'.

Bohte, W., Maat, K. and van Wee, B. (2009). 'Measuring Attitudes in Research on Residential Self-Selection and Travel Behaviour: A Review of Theories and Empirical Research'. In: *Transport Reviews* 29.3, pp. 325–357. DOI: 10.1080/01441640902808441.

Bonham, J., Johnson, M. and Burton, R. (2015). *Cycling Futures*. Adelaide (Aus): University of Adelaide Press.

Bopp, M., Kaczynski, A. and Besenyi, G. (2012). 'Active commuting influences among adults'. In: *Prev Med* 54.3-4, pp. 237–241. DOI: 10.1016/j.ypmed.2012.01.016.

Brüggen, E. et al. (2011). 'Individual Differences in Motivation to Participate in Online Panels: The Effect on Response Rate and Response Quality Perceptions'. In: *International Journal of Market Research* 53.3, pp. 2–19.

Bryman, A. (2016). *Social Research Methods*. Fifth Edit. London: Oxford University Press.

Buehler, R. and Dill, J. (2015). 'Bikeway Networks: A Review of Effects on Cycling'. In: *Transport Reviews* 36.1, pp. 9–27. DOI: 10.1080/01441647.2015.1069908.

Buehler, R. and Pucher, J. (2011). 'Cycling to work in 90 large American cities: new evidence on the role of bike paths and lanes'. In: *Transportation* 39.2, pp. 409–432. DOI: 10.1007/s11116-011-9355-8.

Burbidge, S. K. (2008). 'Evaluating the Impact of Neighborhood Trail Development on Active Travel Behavior and Overall Physical Activity'. PhD thesis.

Carroll, J. et al. (2014). *Jersey Scrutiny review: Compulsory wearing of cycle helmets*.

Caulfield, B., Brick, E. and McCarthy, O. T. (2012). 'Determining bicycle infrastructure preferences – A case study of Dublin'. In: *Transportation Research Part D: Transport and Environment* 17.5, pp. 413–417. DOI: 10.1016/j.trd.2012.04.001.

Cavill Adrian, N. D. and England, C. (2007). *Cycling and Health: What's the evidence?*

Caygill, M. (2014). 'Public Attitudes to Long Distance Travel and Perceptions of High Speed Rail'. PhD thesis. Newcastle UK,

City of Copenhagen (2011). 'Long-term Bicycle Plan 2012-2016'. In:

City of Copenhagen (2014). *Focus on cycling: Copenhagen guidelines for the design of road projects*. Copenhagen.

City of Copenhagen (2015). *Copenhagen city of cyclists: The bicycle account 2014*. Copenhagen.

Clayton, W. and Musselwhite, C. (2013). 'Exploring changes to cycle infrastructure to improve the experience of cycling for families'. In: *Journal of Transport Geography* 33, pp. 54–61. DOI: 10.1016/j.jtrangeo.2013.09.003.

Cohen, J. (1992). 'A Power Primer'. In: *Psychological Bulletin* 112.1, pp. 155–159.

Cohen, L., Manion, L. and Morrison, K. (2011). *Research Methods in Education*. ISBN: 0-203-02905-4. DOI: 10.1111/j.1467-8527.2007.00388{_}4.x.

Comrey, A. L. (1988). 'Factor-analytic methods of scale development in personality and clinical psychology'. In: *Journal of Consulting and Clinical Psychology* 56.5, pp. 754–761.

Conover, W. J. and Iman, R. (1979). *On multiple-comparisons procedures*. Vancouver: Los Alamos Sci. Lab. Tech. Rep. LA-7677-MS.

Costello, A. B. and Osborne, J. W. (2005). 'Best Practices in Exploratory Factor Analysis: Four Recommendations for Getting the Most From Your Analysis'. In: *Practical Assessment, Research & Evaluation* 10.7, pp. 1–9.

Couper, M. P. (2000). 'Web Surveys: A Review of Issues and Approaches'. In: *Public Opinion Quarterly* 64, pp. 464–494.

CROW (2007). *Design manual for bicycle traffic*. Amsterdam, NL.

Curnow, W. J. (2005). 'The Cochrane Collaboration and bicycle helmets'. In: *Accid Anal Prev* 37.3, pp. 569–573. DOI: 10.1016/j.aap.2005.01.009.

Cycling England (2009). *Cycling demonstration towns: Monitoring project report 2006-2009 - Appendix*.

Daley, M. and Rissel, C. (2011). 'Perspectives and images of cycling as a barrier or facilitator of cycling'. In: *Transport Policy* 18.1, pp. 211–216. ISSN: 0967070X. DOI: 10.1016/j.tranpol.2010.08.004. URL: http://dx.doi.org/10.1016/j.tranpol.2010.08.004.

Davies, D. G., Halliday, M. E. et al. (1997). *Attitudes to cycling: a qualitative study and conceptual framework*. London.

Davies, D. G., Hartley, E. and Transport Research Laboratory (1999). *New cycle owners: expectations and experiences*.

De Vries, H. et al. (1998). 'Differential beliefs, perceived social influences, and self-efficacy expectations among smokers in various motivational phases'. In: *Preventive Medicine* 27.5 I, pp. 681–689. ISSN: 00917435. DOI: 10.1006/pmed.1998.0344.

Deenihan, G. and Caulfield, B. (2014). 'Estimating the health economic benefits of cycling'. In: *Journal of Transport & Health*. DOI: 10.1016/j.jth.2014.02.001.

Department for Transport (1999). *Cycling for Better Health*. London.

Department for Transport (2013a). *Detailed Guidance on Social and Distributional Impacts of Transport Interventions - TAG Unit 3.17*. London.

Department for Transport (2013b). *Door to Door: A strategy for improving sustainable transport integration*. London.

Department for Transport (2013c). *National Travel Survey 2012: Statistical release*. London.

Department for Transport (2014a). *Reported Road Casualties Great Britain: 2013 Annual Report - Focus on Pedal Cyclists*.

Department for Transport (2014b). *TAG Unit A5.1: Active mode appraisal*. London.

Department for Transport (2016a). *Cycling and Walking Investment Strategy*. London.

Department for Transport (2016b). *Local Area Walking and Cycling Statistics: England, 2014/15*. London.

Department for Transport (2016c). *National Travel Survey: 2015*. London.

Department for Transport (2016d). *Transport Statistics Great Britain*.

Department for Transport (2017). *Pedal Cycle Traffic (TRA04)*. URL: https://www.gov.uk/government/statistical-data-sets/tra04-pedal-cycle-traffic.

Department of Transport (1996). *The National Cycling Strategy*.

Dill, J. and McNeil, N. (2013). 'Four types of cyclists? Examination of typology for better understanding of bicycling behavior and potential'. In: *Transportation Research Record: Journal of the Transportation Research Board* 2387, pp. 129–138.

Dill, J. and Carr, T. (2003). 'Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them– Another Look'. In: *Transportation Research Record: 79-83* (1578), pp. 79–83.

Dill, J. and Voros, K. (2006). 'Factors affecting bicycling demand: Initial survey findings from the Portland region'. In: *Transportation Research Record* 2031, pp. 9–17.

ESOMAR (2012). *28 Questions to Help Buyers of Online Samples*. Amsterdam, NL.

Esposito Vinzi, V. et al. (2010). *Handbook of Partial Least Squares: Concepts, Methods and Applications*. Berlin: Springer. ISBN: 978-3-540-32825-4.

Ettema, D. and Nieuwenhuis, R. (2017). 'Residential self-selection and travel behaviour: What are the effects of attitudes, reasons for location choice and the built environment?' In: *Journal of Transport Geography* 59, pp. 146–155. DOI: 10.1016/j.jtrangeo.2017.01.009.

European Environment Agency (2013). *A closer look at urban transport - TERM 2013: transport indicators tracking progress towards environmental targets in Europe*.

Eyer, A. and Ferreira, A. (2015). 'Taking the tyke on a bike: mothers' and childless women's space & time geographies in Amsterdam compared'. In: *Environment and Planning A* 47.3, pp. 691–708. DOI: 10.1068/a140373p.

Fitt, H. (2014). *MAMILs, eco-warriors and fitness freaks: How the social meanings around transport influence everyday cycling practices*. Newcastle.

Fornell, C. and Larcker, D. F. (1981). 'Structural Equation Models with Unobservable Variables and Measurement Error'. In: *Journal of Marketing Research* 18.1, pp. 39–50.

Forth, J. et al. (2010). 'Survey errors and survey costs: a response to Timming's critique of the Survey of Employees Questionnaire in WERS 2004'. In: *Work, employment and society* 24.3, pp. 578–590. DOI: 10.1177/0950017010371647.

Fraser, S. D. and Lock, K. (2011). 'Cycling for transport and public health: a systematic review of the effect of the environment on cycling'. In: *Eur J Public Health* 21.6, pp. 738–743. DOI: 10.1093/eurpub/ckq145.

Frings, D., Rose, A. and Ridley, A. M. (2012). 'Bicyclist Fatalities Involving Heavy Goods Vehicles: Gender Differences in Risk Perception, Behavioral Choices, and Training'. In: *Traffic Injury Prevention* 13.5, pp. 493–498. ISSN: 15389588. DOI: 10.1080/15389588.2012.664796.

Füssl, E. and Haupt, J. (2017). 'Understanding cyclist identity and related interaction strategies. A novel approach to traffic research'. In: *Transportation Research Part F: Traffic Psychology and Behaviour* 46, pp. 329–341. DOI: 10.1016/j.trf.2016.08.003.

Gatersleben, B. and Appleton, K. M. (2007). 'Contemplating cycling to work: Attitudes and perceptions in different stages of change'. In: *Transportation Research Part A: Policy and Practice* 41.4, pp. 302–312. DOI: 10.1016/j.tra.2006.09.002.

Gatersleben, B. and Haddad, H. (2010). 'Who is the typical bicyclist?' In: *Transportation Research Part F: Traffic Psychology and Behaviour* 13.1, pp. 41–48. DOI: 10.1016/j.trf.2009.10.003.

Geller, R. (2006). *Four Types of Cyclists*. Portland, Or.

Giles-Corti, B. et al. (2016). *City planning and population health: a global challenge*. DOI: 10.1016/S0140-6736(16)30066-6.

Golbuff, L. and Aldred, R. (2012). *Cycling Policy in the UK: A historical and thematic overview*.

Goodman, A., Panter, J. et al. (2013). 'Effectiveness and equity impacts of town-wide cycling initiatives in England: a longitudinal, controlled natural experimental study'. In: *Soc Sci Med* 97, pp. 228–237. DOI: 10.1016/j.socscimed.2013.08.030.

Goodman, A., Sahlqvist, S., Ogilvie, D. and IConnect Consortium (2013). 'Who uses new walking and cycling infrastructure and how? Longitudinal results from the UK iConnect study'. In: *Prev Med* 57.5, pp. 518–524. DOI: 10.1016/j.ypmed.2013.07.007.

Goodman, A. (2013). 'Walking, cycling and driving to work in the English and Welsh 2011 census: trends, socio-economic patterning and relevance to travel behaviour in general'. In: *PLoS One* 8.8, e71790. DOI: 10.1371/journal.pone.0071790.

Goodman, A., Sahlqvist, S. and Ogilvie, D. (2014). 'New Walking and Cycling Routes and Increased Physical Activity: One- and 2-Year Findings From the UK iConnect Study'. In: *Research and Practice* 104.9, pp. 38–46. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4151955/.

Great Britain (2008). *Climate Change Act*. London.

Green, J. et al. (2014). *On the buses: a mixed-method evaluation of the impact of free bus travel for young people on the public health*. DOI: 10.3310/phr02010.

Guell, C. et al. (2012). 'Towards a differentiated understanding of active travel behaviour: using social theory to explore everyday commuting'. In: *Soc Sci Med* 75.1, pp. 233–239. DOI: 10.1016/j.socscimed.2012.01.038.

Hair, J. F., Sarstedt, M. et al. (2011). 'An assessment of the use of partial least squares structural equation modeling in marketing research'. In: *Journal of the Academy of Marketing Science* 40.3, pp. 414–433. DOI: 10.1007/s11747-011-0261-6.

Hair, J., Mult, G. T. et al. (2014). *A primer on Partial Least Squares Structural Equation Modelling (PLS-SEM)*. Thousand Oaks California USA: SAGE Publications Inc.

Hancock, G. R. and Mueller, R. (2013). *Structural equation modeling: A second course*. Charlotte, NC.: Information Age Publishing. ISBN: 1623962463, 9781623962463.

Handy, S. L., Xing, Y. and Buehler, T. J. (2010). 'Factors associated with bicycle ownership and use: a study of six small U.S. cities'. In: *Transportation* 37.6, pp. 967–985. DOI: 10.1007/s11116-010-9269-x.

Harms, L., Bertolini, L. and Brömmelstroet, M. T. (2015). 'Performance of Municipal Cycling Policies in Medium-Sized Cities in the Netherlands since 2000'. In: *Transport Reviews* 36.1, pp. 134–162. DOI: 10.1080/01441647.2015.1059380.

Hartog, J. J. de et al. (2010). 'Do the health benefits of cycling outweigh the risks?' In: *Environ Health Perspect* 118.8, pp. 1109–1116. DOI: 10.1289/ehp.0901747.

Heesch, K. C., Sahlqvist, S. and Garrard, J. (2012). 'Gender differences in recreational and transport cycling: a cross-sectional mixed-methods comparison of cycling patterns, motivators, and constraints'. In: *International Journal of Behavioral Nutrition and Physical Activity* 9.106, pp. 1–12.

Heinen, E. (2011). 'Bicycle Commuting'. PhD thesis. Delft, The Netherlands.

Heinen, E. (2016). 'Identity and travel behaviour: A cross-sectional study on commute mode choice and intention to change'. In: *Transportation Research Part F: Traffic Psychology and Behaviour* 43, pp. 238–253. DOI: 10.1016/j.trf.2016.10.016.

Heinen, E., Maat, K. and van Wee, B. (2011). 'The role of attitudes toward characteristics of bicycle commuting on the choice to cycle to work over various distances'. In: *Transportation Research Part D: Transport and Environment* 16.2, pp. 102–109. DOI: 10.1016/j.trd.2010.08.010.

Heinen, E., van Wee, B. and Maat, K. (2010). 'Commuting by Bicycle: An Overview of the Literature'. In: *Transport Reviews* 30.1, pp. 59–96. DOI: 10.1080/01441640903187001.

Henseler, J. (2012). 'PLS-MGA: A Non-Parametric Approach to Partial Least Squares-based Multi-Group Analysis'. In: *Studies in Classification, Data Analysis, and Knowledge Organization*, pp. 495–501. DOI: 10.1007/978-3-642-24466-7.

Henseler, J., Hubona, G. and Ray, P. A. (2016). 'Using PLS path modeling in new technology research: updated guidelines'. In: *Industrial Management & Data Systems* 116.1, pp. 2–20. DOI: 10.1108/imds-09-2015-0382.

Hoffmann, M. L. and Lugo, A. (2014). 'Who is 'World Class'? Transportation Justice and Bicycle Policy'. Melody Lynn Hoffmann. In: *Urbanities* 4.1.

Hopkinson, P. and Wardman, M. (1996). 'Evaluating the demand for new cycle facilities'. In: *Transport Policy* 4.3, pp. 241–249.

Horton, D., Rosen, P. and Cox, P. (2007). *Cycling and Society*. London: Ashgate.

Hulland, J. (1999). 'Use of partial least squares (PLS) in strategic management research: a review of four recent studies'. In: *Strategic Management Journal* 20.2, pp. 195–204.

Jamieson, S. (2004). 'Likert scales: how to (ab)use them'. In: *Med Educ* 38.12, pp. 1217–1218. DOI: 10.1111/j.1365-2929.2004.02012.x.

Jensen, O. B. (2013). *Staging Mobilities*. New York: Routledge.

Jones, P. and Lucas, K. (2012). 'The social consequences of transport decision-making: clarifying concepts, synthesising knowledge and assessing implications'. In: *Journal of Transport Geography* 21, pp. 4–16. DOI: 10.1016/j.jtrangeo.2012.01.012.

Jones, T., Chatterjee, K. et al. (2016). *cycle BOOM. Design for lifelong health and wellbeing. Summary of key findings and recommendations*. Oxford.

Kaplan, D. (2008). *Structural equation modeling: Foundations and extensions*. Vol. 10. Vancouver: Sage Publications.

Kline, P. (2014). *An easy guide to factor analysis*. Routledge.

Krosnick, J. A. et al. (2002). 'The impact of" no opinion" response options on data quality: Non-attitude reduction or an invitation to satisfice?' In: *Public Opinion Quarterly* 66.4, pp. 371–403.

Laird, J., Page, M. and Shen, S. (2013). 'The value of dedicated cyclist and pedestrian infrastructure on rural roads'. In: *Transport Policy* 29, pp. 86–96. DOI: 10.1016/j.tranpol.2013.04.004.

Lam, T. F. (2017). 'Hackney: a cycling borough for whom?' In: *Applied Mobilities*, pp. 1–18. DOI: 10.1080/23800127.2017.1305151.

Ligtermoet, D. (2006). *Continuous and integral: The cycling policies of Groningen and other European cycling cities*. Rotterdam (NL).

Lois, D., Moriano, J. A. and Rondinella, G. (2015). 'Cycle commuting intention: A model based on theory of planned behaviour and social identity'. In: *Transportation Research Part F: Traffic Psychology and Behaviour* 32, pp. 101–113. DOI: 10.1016/j.trf.2015.05.003.

Long, J. et al. (2009). *A Systematic Review of the Literature on Black and Minority Ethnic Communities in Sport and Physical Recreation*.

Louviere, J. J. and Islam, T. (2008). 'A comparison of importance weights and willingness-to-pay measures derived from choice-based conjoint, constant sum scales and best–worst scaling'. In: *Journal of Business Research* 61.9, pp. 903–911. DOI: 10.1016/j.jbusres.2006.11.010.

Lovelace, R. et al. (2016). 'The Propensity to Cycle Tool: An open source online system for sustainable transport planning'. In: *ArXiv:1509.04425 [Cs]*. URL: http://arxiv.org/abs/1509.04425/.

Lumsdon, L. and Tolley, R. (2001). 'The National Cycle Strategy in the UK: to what extent have local authorities adopted its model strategy approach?' In: *Journal of Transport Geography* 9.4, pp. 293–301. DOI: http://dx.doi.org/10.1016/S0966-6923(01)00022-9.

Ma, L. and Dill, J. (2016). 'Do people's perceptions of neighborhood bikeability match "Reality"?' In: *Journal of Transport and Land Use*. DOI: 10.5198/jtlu.2015.796.

Madsen, T. (2013). 'Transport cycling behavior: Associations between the built environment and transport cycling in Denmark'. PhD thesis. Odense.

Majumdar, B. B. and Mitra, S. (2015). 'Identification of factors influencing bicycling in small sized cities: A case study of Kharagpur, India'. In: *Case Studies on Transport Policy* 3.3, pp. 331–346. DOI: 10.1016/j.cstp.2014.09.002.

McCormack, G. R. and Shiell, A. (2011). 'In search of causality: a systematic review of the relationship between the built environment and physical activity among adults'. In: *Int J Behav Nutr Phys Act* 8, p. 125. DOI: 10.1186/1479-5868-8-125.

Meggs, J. et al. (2012). *Best Practices in Cycling*.

Morgan, D., Krueger, R. A. and King, J. A. (1998). *Focus Group Kit*. Vol. 1. Thousand Oaks California USA, SAGE Publications, ISBN: 9780761908180.

Muñoz, B., Monzon, A. and Lois, D. (2013). 'Cycling Habits and Other Psychological Variables Affecting Commuting by Bicycle in Madrid, Spain'. In: *Transportation Research Record Journal of the Transportation Research Board* 2382.1, pp. 1–9.

Muñoz, B., Monzon, A. and López, E. (2016). 'Transition to a cyclable city: Latent variables affecting bicycle commuting'. In: *Transportation Research Part A: Policy and Practice* 84, pp. 4–17. DOI: 10.1016/j.tra.2015.10.006.

Næss, P. (2009). 'Residential Self-Selection and Appropriate Control Variables in Land Use: Travel Studies'. In: *Transport Reviews* 29.3, pp. 293–324. DOI: 10.1080/01441640802710812.

Nancarrow, C. and Tapp, A. (2014). 'Online access panels for surveys on public health and epidemiology'. University of West England.

NHS (2009). *The General Practice Physical Activity Questionnaire (GPPAQ)*.

Nunnally, J. C. and Bernstein, I. H. (1994). 'Validity'. In: *Psychometric theory*, pp. 99–132.

Office for National Statistics. *Deriving the NS-SEC: self-coded method*.

Office for National Statistics (2011a). *2011 Census: Quick Statistics for England and Wales, March 2011*. London. URL: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/2011censusquickstatisticsforenglandandwales/2013-01-30.

Office for National Statistics (2011b). *Household Questionnaire*. DOI: http://dx.doi.org/10.5257/census/aggregate-2001-2. URL: https://www.ons.gov.uk/file?uri=/census/censustransformationprogramme/consultations/the2021censusinitialviewoncontentforenglandandwales/2011censusquestionnaireenglandh1.pdf.

Office for National Statistics (2014). *2011 Census Analysis - Cycling to Work*. London.

Office for National Statistics (2016). 'Population Estimates for UK, England and Wales, Scotland and Northern Ireland: mid-2015'. In: *Statistical bulletin* 30/10/2015. URL: http://www.ons.gov.uk/ons/publications/all-releases.html?definition=tcm%3A77-22371.

Office for National Statistics (2017). *Internet access – households and individuals 2017*.

Ogilvie, D., Bull, F., Cooper, A. et al. (2012). 'Evaluating the travel, physical activity and carbon impacts of a 'natural experiment' in the provision of new walking and cycling infrastructure: methods for the core module of the iConnect study'. In: *BMJ Open* 2.1, e000694. DOI: 10.1136/bmjopen-2011-000694.

Ogilvie, D., Bull, F., Powell, J. et al. (2011). 'An applied ecological framework for evaluating infrastructure to promote walking and cycling: the iConnect study'. In: *Am J Public Health* 101.3, pp. 473–481. DOI: 10.2105/AJPH.2010.198002.

Oja, P. et al. (2011). 'Health benefits of cycling: a systematic review'. In: *Scand J Med Sci Sports* 21.4, pp. 496–509. DOI: 10.1111/j.1600-0838.2011.01299.x.

O'Loughlin, C. and Coenders, G. (2004). 'Estimation of the European Customer Satisfaction Index: Maximum Likelihood versus Partial Least Squares. Application to Postal Services'. In: *Total Quality Management & Business Excellence* 15.9-10, pp. 1231–1255. DOI: 10.1080/1478336042000255604.

Ortúzar, J. d. D. and Willumsen, L. G. (2011). *Modelling Transport*. Fourth. London.

Paige Willis, D., Manaugh, K. and El-Geneidy, A. (2013). 'Uniquely satisfied: Exploring cyclist satisfaction'. In: *Transportation Research Part F: Traffic Psychology and Behaviour* 18, pp. 136–147. DOI: 10.1016/j.trf.2012.12.004.

Parkin, J. (2003). 'Comparisons of cycle proportions for the journey to work from the 1981, 1991 and 2001 censuses'. In: *Traffic Engineering and Control* 44.8, pp. 299–302.

Parkin, J., Ryley, T. J. and Jones, T. J. (2007). 'Barriers to cycling: an exploration of quantitative analyses'. In: *Civil Engineering*.

Passafaro, P. et al. (2014). 'The bicycle and the city: Desires and emotions versus attitudes, habits and norms'. In: *Journal of Environmental Psychology* 38, pp. 76–83. DOI: 10.1016/j.jenvp.2013.12.011.

Piatkowski, D. P. and Marshall, W. E. (2015). 'Not all prospective bicyclists are created equal: The role of attitudes, socio-demographics, and the built environment in bicycle commuting'. In: *Travel Behaviour and Society* 2.3, pp. 166–173. DOI: 10.1016/j.tbs.2015.02.001.

Pooley, C. G., Horton, D. et al. (2013). 'Policies for promoting walking and cycling in England: A view from the street'. In: *Transport Policy* 27, pp. 66–72. DOI: 10.1016/j.tranpol.2013.01.003.

Pooley, C. G., Tight, M. et al. (2011). *Understanding walking and cycling: Summary of key findings and recommendations*. Lancaster.

Prins, R. G. et al. (2016). 'Causal pathways linking environmental change with health behaviour change: Natural experimental study of new transport infrastructure and cycling to work'. In: *Prev Med* 87, pp. 175–182. DOI: 10.1016/j.ypmed.2016.02.042.

Prochaska, J. O. and Velicer, W. F. (1997). 'The Transtheoretical Model of Health Behavior Change'. In: *American Journal of Health Promotion* 12.1, pp. 38–48.

Pucher, J., Dill, J. and Handy, S. (2010). 'Infrastructure, programs, and policies to increase bicycling: an international review'. In: *Preventive Medicine* 50.1, pp. 106–25. DOI: 10.1016/j.ypmed.2009.07.028.

Pucher, J. and Buehler, R. (2008). 'Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany'. In: *Transport Reviews* 28.4, pp. 495–528. DOI: 10.1080/01441640701806612.

Pucher, J., Buehler, R. and Seinen, M. (2011). 'Bicycling renaissance in North America? An update and re-appraisal of cycling trends and policies'. In: *Transportation Research Part A: Policy and Practice* 45.6, pp. 451–475. DOI: 10.1016/j.tra.2011.03.001.

Qureshi, I. and Compeau, D. (2009). 'Assessing between-group differences in Information Systems research: a comparison of covariance- and component-based SEM'. Israr Qureshi. In: *MIS Quarterly* 33.1, pp. 197–214.

Reise, S. P., Waller, N. G. and Comrey, A. L. (2000). 'Factor analysis and scale revision'. In: *Psychological Assessment* 12.3, pp. 287–297. DOI: 10.1037//1040-3590.12.3.287.

Respondi (2015). *Access Panels: Really understanding your target group*. URL: http://www.respondi.com/en/.

Rietveld, P. and Daniel, V. (2004). 'Determinants of bicycle use: do municipal policies matter?' In: *Transportation Research Part A: Policy and Practice* 38.7, pp. 531–550. DOI: 10.1016/j.tra.2004.05.003.

Rigdon, E. E. (2016). 'Choosing PLS path modeling as analytical method in European management research: A realist perspective'. In: *European Management Journal* 34.6, pp. 598–605. DOI: 10.1016/j.emj.2016.05.006.

Ringle, C. M. and Sarstedt, M. (2015). 'Gain more insight from your PLS-SEM results: The importance-performance map analysis'. In: *Industrial Management & Data Systems* 116.9, pp. 1865–1886. ISSN: 02635577. DOI: 10.1108/IMDS-07-2015-0302.

Rönkkö, M. and Evermann, J. (2013). 'A Critical Examination of Common Beliefs About Partial Least Squares Path Modeling'. In: *Organizational Research Methods* 16.3, pp. 425–448. DOI: 10.1177/1094428112474693.

Rönkkö, M., McIntosh, C. N. et al. (2016). 'Partial least squares path modeling: Time for some serious second thoughts'. In: *Journal of Operations Management* 47-48, pp. 9–27. DOI: 10.1016/j.jom.2016.05.002.

Rose, D. and Pevalin, D. (2010). *Re-basing the NS-SEC on SOC2010*.

Ryan, A. M. and Spash, C. L. (2011). 'Is WTP an attitudinal measure? Empirical analysis of the psychological explanation for contingent values'. In: *Journal of Economic Psychology* 32.5, pp. 674–687. DOI: 10.1016/j.joep.2011.07.004.

Ryan, G. W. and Bernard, H. R. (2003). 'Techniques to Identify Themes'. In: *Field Methods* 15.1, pp. 85–109. DOI: 10.1177/1525822x02239569.

Sahlqvist, S. L. and Heesch, K. C. (2012). 'Characteristics of Utility Cyclists in Queensland, Australia: An Examination of the Associations Between Individual, Social, and Environmental Factors and Utility Cycling'. In: *Journal of Physical Activity and Health* 9, pp. 818–828.

Sanchez, G. (2013). *PLS Path Modeling with R*. Berkeley. URL: http://www.gastonsanchez.com/PLS_Path_Modeling_with_R.pdf.

Sarstedt, M., Hair, J. F. et al. (2016). 'Estimation issues with PLS and CBSEM: Where the bias lies!' In: *Journal of Business Research* 69.10, pp. 3998–4010. DOI: 10.1016/j.jbusres.2016.06.007.

Sarstedt, M., Henseler, J. and Ringle, C. M. (2011). 'Multigroup Analysis in Partial Least Squares (PLS) Path Modeling: Alternative Methods and Empirical Results'. In: *Measurement and Research Methods in International Marketing*. Vol. 22. Emerald Group Publishing Limited, pp. 195–218. ISBN: 1474-7979. DOI: 10.1108/s1474-7979(2011)0000022012.

Scheiner, J. and Holz-Rau, C. (2012). 'Gendered travel mode choice: a focus on car deficient households'. In: *Journal of Transport Geography* 24, pp. 250–261. DOI: 10.1016/j.jtrangeo.2012.02.011.

Schoner, J. E., Cao, J. and Levinson, D. M. (2015). 'Catalysts and magnets: Built environment and bicycle commuting'. In: *Journal of Transport Geography* 47, pp. 100–108. DOI: 10.1016/j.jtrangeo.2015.07.007.

Shaghaghi, A., Bhopal, R. S. and Sheikh, A. (2011). 'Approaches to Recruiting 'Hard-To-Reach' Populations into Re-search: A Review of the Literature.' In: *Health promotion perspectives* 1.2, pp. 86–94. ISSN: 2228-6497. DOI: 10.5681/hpp.2011.009. URL: /pmc/articles/PMC3963617/?report=abstract.

Sheskin, D. J. (2003). *Handbook of parametric and nonparametric statistical procedures*. New York: CRC Press.

Shove, E., Pantzar, M. and Watson, M. (2012). *The Dynamics of Social Practice: Everyday life and how it changes*. London: Sage Publications.

Shove, E. (2010). 'Beyond the ABC: climate change policy and theories of social change'. In: *Environment and Planning A* 42, pp. 1273–1285.

Sport England (2016). *Active People Interactive*. URL: `http://activepeople.sportengland.org/`.

Spotswood, F. et al. (2015). 'Analysing cycling as a social practice: An empirical grounding for behaviour change'. In: *Transportation Research Part F: Traffic Psychology and Behaviour* 29, pp. 22–33. DOI: `10.1016/j.trf.2014.12.001`.

Stahlbock, R., Crone, S. F. and Lessmann, S. (2010). 'Response-Based Segmentation Using Finite Mixture Partial Least Squares'. In: *Data Mining*. Ed. by R. Stahlbock, S. F. Crone and S. Lessmann. Vol. 8. Springer US. ISBN: 1934-3221 1934-3213. DOI: `10.1007/978-1-4419-1280-0`.

Statistics, T. (2010). *Factsheet 1: Overview of transport greenhouse gas emissions*. Tech. rep. London, p2.

Steer Davies Gleave and Transport for London (2012). *Cycle route choice - Final survey and model report*. London.

Stoffers, M. (2012). 'Cycling as heritage: Representing the history of cycling in the Netherlands'. In: *The Journal of Transport History* 33.1, pp. 92–114. DOI: `10.7227/tjth.33.1.7`.

Sunstein, C. R. (2015). *The Mischievous Science of Richard Thaler*. URL: `http://newramblerreview.com/book-reviews/economics/the-mischievous-science-of-richard-thaler`.

Survey Gizmo (2015). *No Title*. URL: `https://app.surveygizmo.com/`.

Sustrans (2014a). *Millions of people on the move: Usage and benefits of the National Cycle Network in 2013*.

Sustrans (2014b). *Sustrans Design Manual: Handbook for cycle-friendly design*. Tech. rep. Bristol.

Sustrans (2017). *The Infrastructure Impact Tool*. Bristol.

Tenenhaus, M. (2008). 'Component-based Structural Equation Modelling'. France.

Transport for London (2010). *Analysis of Cycling Potential – Travel in London*. London.

Transport for London (2011). 'What are the barriers to cycling amongst ethnic minority groups and people from deprived backgrounds?'

Transport for London (2013). *The Mayor's cycling vision for London*. London.

Transport for London (2014). *London Cycling Design Standards*. London.

Tripp, S. D. and Bichelmeyer, B. (1990). 'Rapid prototyping: An alternative instructional design strategy'. In: *Educational Technology Research and Development* 38.1, pp. 31–44. ISSN: 10421629. DOI: 10.1007/BF02298246.

TRT and European Parliament's Committee on Transport and Tourism (2010). *The Promotion of Cycling*. Brussels.

Turner, S. (1994). *The social theory of practices: Tradition, tacit knowledge, and presuppositions*. Vancouver: University of Chicago Press.

Urban Movement & Phil Jones Associates and Transport for London (2014). *International cycling infrastructure best practice study*.

van Wee, B., Rietveld, P. and Meurs, H. (2006). 'Is average daily travel time expenditure constant? In search of explanations for an increase in average travel time'. In: *Journal of Transport Geography* 14.2, pp. 109–122.

Venkatachalam, L. (2004). 'The contingent valuation method: a review'. In: *Environmental Impact Assessment Review* 24.1, pp. 89–124. DOI: 10.1016/s0195-9255(03)00138-0.

Wardman, M., Chintakayala, V. P. K. and Jong, G. de (2016). 'Values of travel time in Europe: Review and meta-analysis'. In: *Transportation Research Part A: Policy and Practice* 94, pp. 93–111. DOI: 10.1016/j.tra.2016.08.019.

Wardman, M., Hatfield, R. and Page, M. (1997). 'The UK national cycling strategy: can improved facilities meet the targets?' In: *Transport Policy* 4.2, pp. 123–133.

Welleman, T., Ministry of Transport Public Works and Water Management and Concorde Vertalingen BV (1999). *The Dutch Bicycle Master Plan: Description and evaluation in an historical context*. The Hague.

Willis, D. P., Manaugh, K. and El-Geneidy, A. (2015). 'Cycling Under Influence: Summarizing the influence of perceptions, attitudes, Devon Paige Willishabits and social environments on cycling for transportation'. In: *International Journal of Sustainable Transportation* 9.8, pp. 565–579.

Woodcock, J., Givoni, M. and Morgan, A. S. (2013). 'Health Impact Modelling of Active Travel Visions for England and Wales Using an Integrated Transport and Health Impact Modelling Tool (ITHIM)'. In: *PLoS One* 8.1, pp. 1–17. DOI: 10.1371/journal.pone.0051462.t00110.1371/journal.pone.0051462.t002.

Yahya, N. (2013). 'Assessment of Service Quality and Satisfaction from Passengers Perspective to Inform Bus Operator Decision Making'. PhD thesis.

Yang, H. H. (2013). 'Green Urban Public Bikes Rental System: A Case Study of Taipei YouBike'. In: *Advanced Materials Research* 723, pp. 968–975. DOI: 10.4028/www.scientific.net/AMR.723.968.

Yang, L. et al. (2010). 'Interventions to promote cycling: systematic review'. In: *BMJ* 341, p. c5293. DOI: 10.1136/bmj.c5293.